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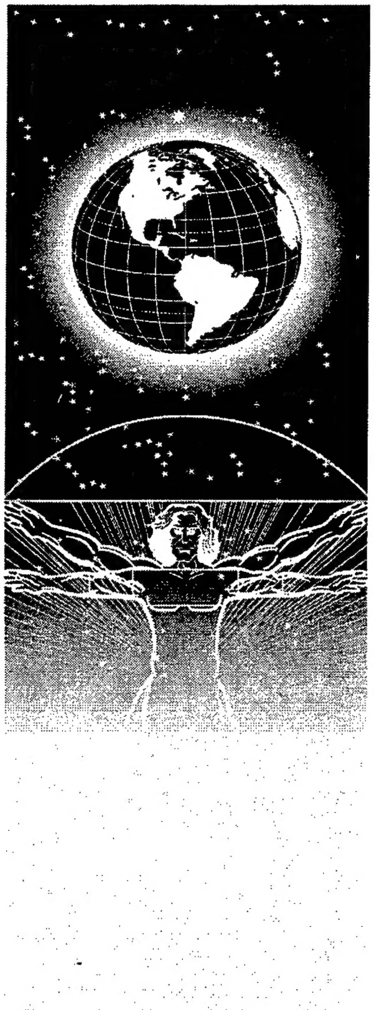

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Space Logistics – Front End Analysis

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Final Report for the Period April 2000 to August 2001

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Mark M. Hoffman

MARK M. HOFFMAN
Deputy Chief
Deployment and Sustainment Division
Air Force Research Laboratory

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The primary objective of this task was to provide a comprehensive review of current logistic functions that support and sustain legacy space systems and to identify potential research opportunities and technology thrusts that could improve or enhance current and future space systems. The outcome of this effort was the identification of approximately 80 space logistics/sustainment deficiencies in current Air Force space systems. In addition, this task also produced a ranked list of 15 potential research concepts from the list of deficiencies for further consideration.

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PREFACE

This final report was performed under the Technology for Readiness and Sustainment (TRS) contract, F33615-99-D-6001, Delivery Order 12, for the Air Force Research Laboratory (AFRL), Sustainment Logistics Branch (HESS), Wright-Patterson AFB, OH. The research covered the time period April 2000 through August 2001. The primary objective of this task was to provide a comprehensive review of current logistic functions that support and sustain legacy space systems and to identify potential research opportunities and technology thrusts that could improve or enhance current and future space systems. The outcome of this effort was the identification of approximately 80 space logistics/sustainment deficiencies in current Air Force space systems. In addition, this task also produced a ranked list of 15 potential research concepts from the list of deficiencies for further consideration.

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GLOSSARY

ABDA	Aircraft Battle Damage Assessment
AFMC	Air Force Materiel Command
AFRL	Air Force Research Laboratory
AFSMC	Air Force Space and Missile Systems Center
AFSPC	Air Force Space Command
AGE	Aerospace Ground Equipment
AI	Artificial Intelligence
ALRMS	Advanced Launch Ranch Maintenance System
ASAT	Anti-Satellite
CAMS	Core Automated Maintenance System
CCAFS	Cape Canaveral Air Force Station
CFE	Contractor Furnished Equipment
COMSAT	Communications Satellite
CONOPS	Concept of Operations
CPATs	Critical Process Assessment Tools
CS	Contractor Support
ECU	Environmental Control Unit
EELV	Evolved Expendable Launch Vehicle
FMEA	Failure Modes and Effects Analysis
FTD	Flight Training Device
GEO	Geosynchronous Earth Orbit
GFP	Government Furnished Property
GOC	General Officer Council
GPS	Global Positioning System
HESS	Logistics Sustainment Branch
IPPD	Integrated Product Process Development
ILS	Integrated Logistics Support
ISA	Intelligent Software Agent
ISR	Intelligence, Surveillance and Reconnaissance
LDST	Logistics Decision Support Tool
LEO	Low Earth Orbit
LMI	Logistics Management Information
LRAT	Launch Readiness Assessment Tool
MAPs	Mission Area Plans
MDC	Maintenance Data Collection
MEO	Medium Earth Orbit
MNS	Mission Needs Statement

NUDET	Nuclear Detonation
O&M	Operations and Maintenance
OOS	On-Orbit Servicing
ORD	Operational Requirements Document
ORU	Orbital Replacement Unit
OTV	Orbital Transfer Vehicle
PME	Prime Mission Equipment
REMIS	Reliability & Maintainability Information System
RLV	Reusable Launch Vehicle
ROI	Return on Investment
RPIE	Real Property Installed Equipment
SBIRS	Space Based Infrared System
SBL	Space Based Laser
SBLF	Space Based Logistics Facility
SBR	Space Based Radar
SE	Support Equipment
SLR	Space Lift Ranges
SLRS	Space Lift Range Sustainment
SMV	Space Maneuvering Vehicle
SOO	Statement of Objectives
SOW	Statement of Work
STG	Space Technology Guide
TDME	Test, Diagnostic and Measuring Equipment
TPIPTs	Technology Planning Integrated Product Teams
TSPR	Total System Performance Responsibility
TSRA	Training System Requirements Analysis
VAFB	Vandenberg Air Force Base

1.0 INTRODUCTION

This report presents the findings, of the Space Sustainment Study conducted from 20 April 2000 through 31 Aug 2001 for the Logistics Sustainment Branch (HESS) of the Human Effectiveness Directorate of the Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio. Applicable contract number: F33615-99-D-6001, Delivery Order Number 12, Task 1.

The AFRL manages science and technology programs supporting all Air Force major commands and agencies. The purpose of this research effort, was to assess the space sustainment requirements for the Air Force Space Command (AFSPC) and the Air Force Space and Missile Systems Center (SMC). AFRL/HESS performs developmental research to improve the effectiveness of Air Force logistics from early systems concepts through production. Until recently, the research conducted by AFRL/HESS has been focused primarily upon aircraft logistics and sustainment deficiencies. With a recent shift of emphasis to an aerospace force, AFRL/HESS is exploring areas of space systems logistics where innovative technologies can make an impact on improving or enhancing the sustainability of Air Force Space Systems.

This study consists of a comprehensive review of current logistics functions that support and sustain legacy space systems, and the identification of potential research opportunities and technology thrusts that could be pursued to improve or enhance the supportability of both current and future space systems. Any new or improved technologies identified in this effort could have application to programs like Space Based Laser (SBL), Space Based Radar (SBR), and Space Based Infrared Systems (SBIRS), and could possibly be used in modifications to existing systems such as the Global Positioning System (GPS) and the Milstar communications satellite (COMSAT).

1.1 BACKGROUND

The report of the January 11, 2001 congressionally chartered Space Commission to "Assess U.S. National Security Space Management and Organization" contains substantial information relative to reorganization of the Air Force to include the impact of current and future space programs. A major reorganization merging the Air Force Space Command (AFSPC) and the Air Force Space and Missile Systems Center (AFSMC) of the Air Force Materiel Command (AFMC) is the direct result of this report and its recommendations. The study team attempted to address the philosophy and recommended directions included in the Space Commission's document as was considered appropriate for this limited study effort.

Current and future military space systems clearly represent the policies of this nation's long-term space power and space force projection and reflect the United States space systems' increasingly decisive role in projecting U.S. military assertiveness around the globe. Sustainability and reconstitution of all United States space assets is key to the future effectiveness and military potential of the nation's spacecraft, payloads, and

platforms. The logistics ground and space-based infrastructure for sustaining these national assets must be as responsive as the equipment they support to enable and sustain increased readiness of America's military ground, sea, air, and space warfighting forces.

The USSPACECOM Space Logistics Master Plan dated 30 June 1995 (currently being updated) defines logistics as the "procurement, distribution, maintenance and replacement of material and personnel." The overall DoD logistics mission is to "ensure quality logistics support to the total force for the full spectrum of operating scenarios."

Currently, the spectrum of Air Force logistics strategies used in supporting and sustaining legacy space systems include a mix of traditional organic and contractor support. Figure 1 illustrates this mix and identifies selected decision factors and strategies considered key inputs to determining the most cost effective, regulatory and legally compliant ratio between organic and contractor provided logistics support.

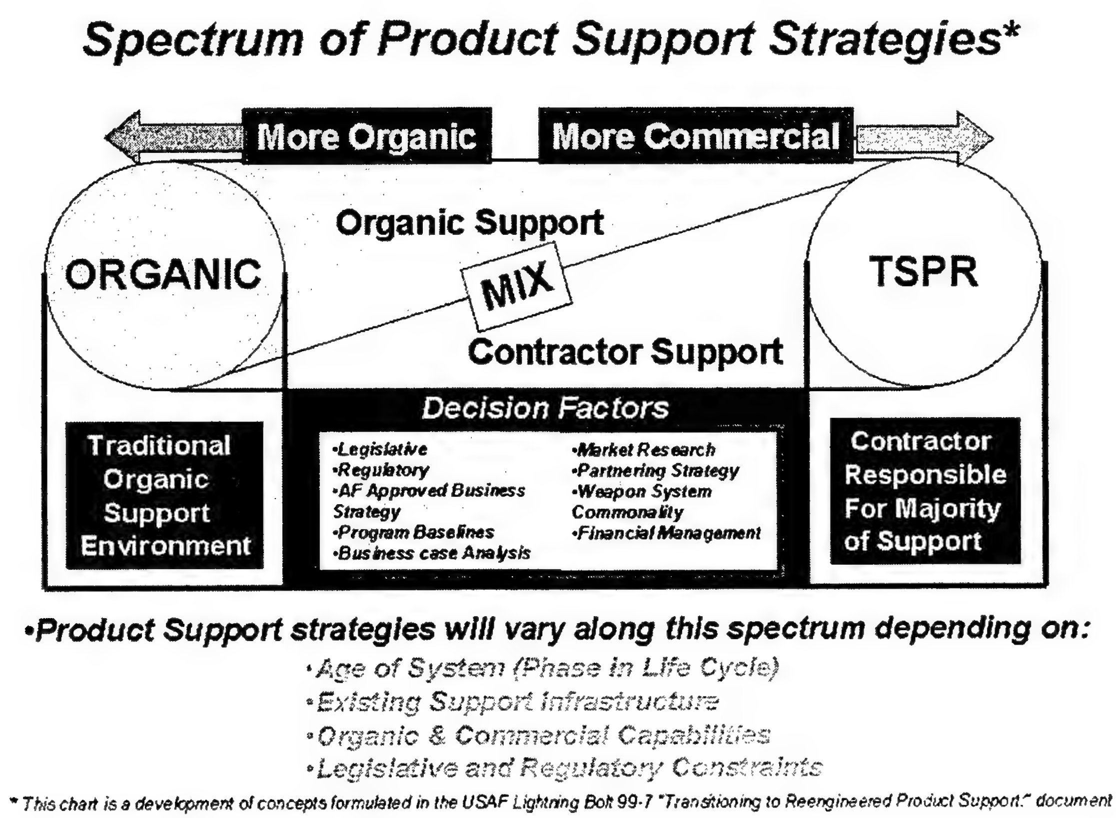

Figure 1: Air Force Logistics Strategies

1.2 APPROACH

The Study Approach and Plan was embodied in the following subtasks:

1. Conduct personnel interviews with AFSMC, AFSPC, and aerospace contractor representatives to identify existing deficiencies in space systems sustainment, develop a prioritized list of Air Force space system sustainment deficiencies.
2. Examine logistics support research areas that have potential to solve the identified deficiencies with application of technology-based solutions.
3. Develop a set of research selection criteria to rank the deficiencies and map them to enabling technologies to aid in focusing AFRL/HESS research concept selection.
4. Apply the above criteria, select and rank (prioritize) the candidate list of research concepts deemed suitable for an AFRL/HESS logistics research program starting in FY 2002 or 2003.
5. Prepare a research program time-phased technology roadmap.

Figure 2 shows the approach used by the study team.

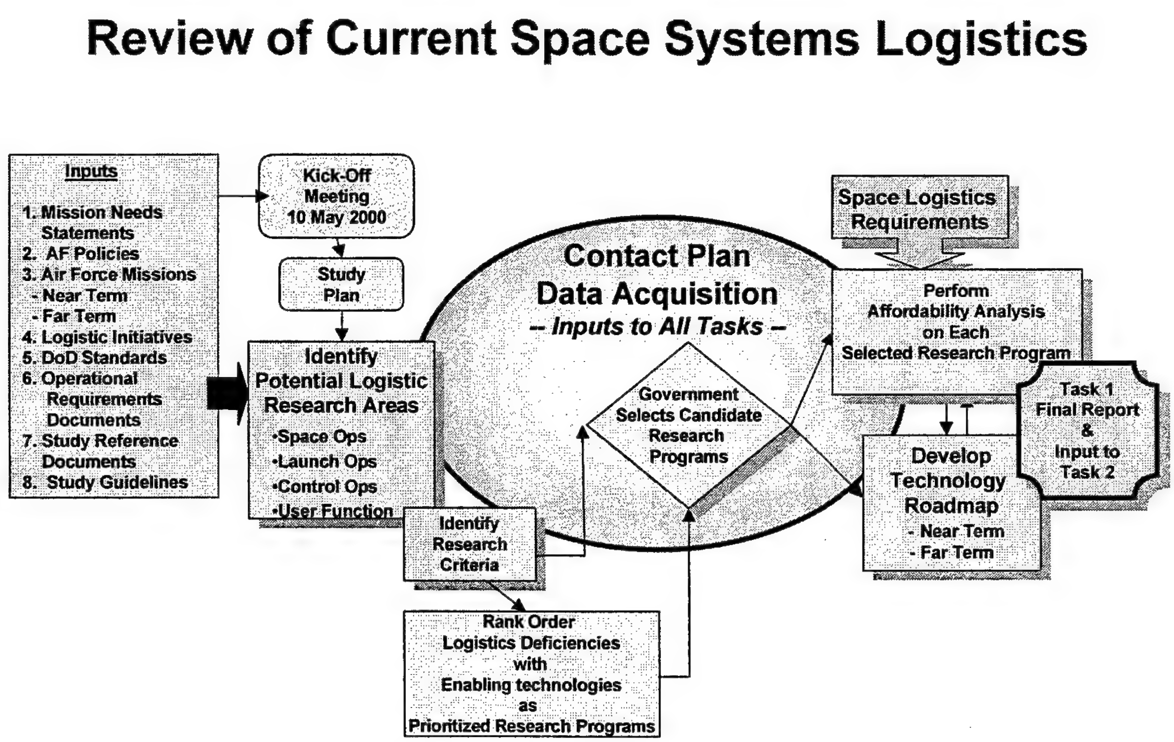

Figure 2: Study Methodology

1.2.1 Study Inputs

This study began with an impressive collection of input documentation and related materials. Air Force Mission Need Statements (MNS), operational acquisition/training policies, definition of Air Force near term (2000-2005) and far term (2006-2010) missions, and recent Operational Requirements Documents (ORD) for space systems. Factored into the study subtasks were logistics initiatives, documentation and tools such as: Flexible Sustainment, Critical Process Assessment Tools (CPATs), Logistics Management Information (LMI), and MIL-HDBK-502 for their applicability to space logistics. Finally, relative DoD Directives and Standards, the thirteen Statement of Work (SOW) Reference Documents in DO-12 study, and the derived Study Guidelines were integrated into the workflow established for the study.

1.2.2 Contact Plan

Central to meeting study objectives was the construction and implementation of a Contact Plan designed to obtain logistics and sustainment deficiency information from developers, users, maintenance experts, and logistics planners. (See Appendix A, Contact Plan). The Plan was implemented in July 2000, and completed in April 2001. Funding constraints and redirection by AFRL/HESS limited the study team from contacting all agencies identified in the plan, however, the information gathered and included in the appendices of this report were sufficient to identify and evaluate the candidate study concepts.

Who was contacted – The Contact Plan featured group meetings, face-to-face interviews, phone interviews, follow-up phone calls, and e-mails with representatives from the Air Force acquisition, sustainment, and user organizations. Additional information was obtained from other government and commercial space related organizations, including the following:

SMC LAAFB	AFRL/VSDD	MILSTAR SPO
Aerospace Corp	HQAFSPC/LG/SC	SMC/Det 9
TRW	ESC/NDCF	SMC/Det 11
Lockheed/Martin	SBL SPO	Spectrum Astro
SBIRS SPO	DARPA	Boeing
DSP SPO	AF Battlelab	Teal Group
GPS SPO	NASA/JSC	DMSP SPO
EELV	Delta Launch /SPO	

21st and 50th Space Wings

Appendix A contains the Contact Plan used by the study team.

Survey Questions – A listing of people contacted and interviewed at the organizations listed above is given in Appendix A-1. To facilitate the interviews, the team generated a series of general questions to lead the opening discussion that then became specific to the technical expertise of the individual being interviewed. The set of questions used to facilitate the surveys is included in Appendix A-2. The questions addressed ten major categories or elements of integrated logistics support, acquisition logistics, and sustainment considerations are show below:

SPACE LOGISTICS ACQUISITION AND SUSTAINMENT CATEGORIES

1.0	Logistics Decisions and Operations
2.0	Technology
3.0	Equipment and Facilities
4.0	Modeling and Simulation
5.0	Supply Support
6.0	Sustaining Engineering
7.0	Packaging, Handling, Storage, and Transportation
8.0	Manpower, Personnel, Training
9.0	Maintenance Planning
10.0	Computer Resources Support

Send Ahead Package – An initial meeting was held with the AFSMC Detachment 11 organization at Peterson AFB to provide an overview of the study objectives and intent followed by face-to-face interviews with members of key organizations responsible for the sustainment of legacy space systems operated and maintained by AFSPC. Det 11 is the primary sustainment organization responsible for space systems support. The Air Force Electronic Systems Center, Detachment 5 is also located at PAFB. ESC/Det 5 provides sustainment support to many of the ground command, control, and communications systems used by AFSPC for operating space assets. Both organizations were surveyed during the study. Prior to this initial meeting, a set of introductory briefing charts was e-mailed to the Det 11 Point of Contact to give the interviewees a preview of the study's content and objectives. This "Send Ahead" package is enclosed in Appendix A-3. As the surveys were extended to include other space sustainment organizations at additional AFSPC locations, the study team presented an abbreviated introductory briefing. A copy of the abbreviated briefing is included at A-3a.

Contact Plan Summary – The successful execution of the Contact Plan was integral to the credibility and utility of the study results. Members of the customer organization (AFRL/HESS) and contractor team (Litton/TASC and bd Systems, Inc.) collaborated on the visits, interviews, and subsequent analysis of the information obtained. The conclusions that were formulated are based on current space system logistics deficiencies identified during the visits and/or derived by the study team. Corrective technologies, research concepts and selection criteria were then established, and a proposed AFRL/HESS Logistics Research program formulated. Details are provided in the sections that follow.

2.0 REVIEW OF CURRENT SPACE SYSTEM LOGISTICS

The study team reviewed current organic and contractor Air Force space logistics approaches from a technical, management, and non-technical perspective. Through the implementation of the Contact Plan the team identified existing discrepancies and several new requirements needed in the logistical process, for both the acquisition logistics and sustainment functions, and subsequently assessed their impact on operational readiness.

The study team associated the deficiencies and requirements identified by the surveys with relevant existing and emerging technologies, and then performed an analysis to generate a list of logistics research concepts that could be candidates for AFRL/HESS research investment. The team's approach for reviewing current space systems logistics included an investigation of Air Force Space Planning and Technology Developments that are underway or planned in each of the space segments shown in Figure 3.

Figure 3 depicts the four basic segments that comprise today's space systems. By examining the breadth of equipment, mission requirements, and operations involved in operating and maintaining space systems, one gains insight into the problem of integrating unique, and often-complex space logistics needs with their associated military space systems.

Air Force Instruction (AFI) 21-108, describes space systems as normally comprised of the four segments described below and shown in Figure 3:

- The Launch Segment includes:
  - The launch vehicle
  - Support Equipment (SE)
  - Real Property Installed Equipment (RPIE)
  - Facilities on the launch base
  - Sites supporting the launch base, such as launch range assets

- The Control Segment includes the equipment that perform the telemetry, tracking, and commanding of orbiting space vehicles:
  - Prime Mission Equipment (PME)
  - SE
  - RPIE
- The Space Segment includes:
  - Spacecraft
  - Other equipment that remains in space

- The User Segment includes the following types of equipment*, other than space-based, that provide navigation data, surveillance data, communication links, and other products to the user:
  - PME
  - SE
  - RPIE

Logistics Requirements for Space Sustainment

- Areas for Improvements are in the Four Basic Space Segments -

Launch	Satellite Operations	Control	User
• Launch Vehicles • Payload Processing • Launch Operations • Range Operations • Reduce cost to orbit	• Ground based • Space based	• Satellite / Sensor telemetry, tracking, command and control systems	• Joint service requirements • O&M Procedures • Training requirements • SOR considerations

Resources for Logistics Support

- Ground and Flight Support Equipment
- Logistics Support Facilities
- Manpower & Personnel
- Training and Training Resources
- Modeling and Simulation
- Maintenance Procedures and Plans
- Replenishment Spares and Repair Parts
- PHS&T Processes and Resources
- Technical Data
- Software/Firmware Supportability
- SOR/LOR considerations

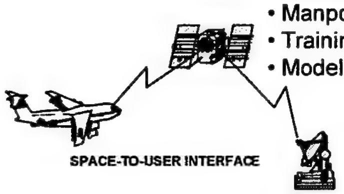

Figure 3: Space Segment Logistics Requirements

*Note that the User Segment equipment may be fixed, mobile, or imbedded in other systems (i.e. GPS receivers or military satellite communication terminals in aircraft, tanks, or ships). Logistics support of the User Segment equipment is normally provided by the using command or government agency. Only AFSPC User systems were considered in this study.

Each segment operates more or less independently and logistical support is segregated into a number of separate support systems with unique capabilities and resources that are driven by each individual program's needs (i.e. "Stovepipe" approach). The challenge for logistics planners and implementers is to ensure that the evolving military space systems have the sustainment support they need when they need it, throughout their life cycle. Each segment was examined by program, and collectively across programs in an effort to identify potential areas for commonality and consolidation of support efforts.

The starting place for the study was to examine and identify deficiencies/requirements that may reside in the resources currently used to logistically support the legacy space segments. In the past, the support systems developed for sustaining space systems have historically been tailored for the specific program being sustained. This method of supporting space systems has contributed over several years of space operations to documented inefficiencies and redundant capabilities.

Contractor Support (CS) may, and usually is, selected for sustainment of several segments of an Air Force space system. In addition, CS may be selected to sustain selected segments, elements, or subsystems, and/or for selected equipment items. Total CS may be procured under a separate logistics contract (from the prime development contract), while selected areas of CS may be included as part of an overall program development contract.

A form of logistics support that is gaining increasing use in the life cycle sustainment of new space systems is "Total System Performance Responsibility" (TSPR). TSPR presented a unique situation to the study team in trying to identify existing deficiencies as candidate concepts for study by AFRL/HESS. Under TSPR, the contractor assumes full responsibility for both the performance of the space system to meet operational needs determined by the using commands, and documented in the ORD, CONOPS, the SOO, and system and subsystem specifications, but also for the life cycle sustainment of the space systems to meet the using command's operational need.

The TSPR approach minimizes government involvement and takes maximum advantage of the commercial market place's capabilities. Under this approach, the government is purchasing a combat capability, and the contractor does whatever is necessary to supply it. The contractor manages all field reliability and integration issues, vendor problems, and obsolete parts. If a system is very complex, software intensive, and prone to design instabilities (due to performance improvement requirements or obsolete parts), this approach receives serious consideration. As described in the HQ AFMC/DR homepage: "...TSPR will be used with increased frequency as the means to divest the government program offices from system integration responsibilities." "Under TSPR, the government continues to control system functional requirements while industry controls design/product requirements. Thus, the contractor is fully responsible for the integration of all systems, subsystems, components, government furnished property (GFP), contractor furnished equipment (CFE) and support equipment, and must ensure no performance degradation after integration."

A specific example of the application of TSPR on a current space system under development is shown in the Space Based Infrared System (SBIRS) contract. The SBIRS High contract, states in part, "—the contractor agrees to assume total responsibility for the system performance in accordance with the terms and performance requirements of the contract, and to furnish all necessary effort, skills, and expertise to within the estimated cost and award fee pool of the contract. (Logistics

support responsibilities) of the contractor under TSPR include, but are not limited to — performing functional and procedural integration of all SBIRS elements, providing support/sustainment infrastructures --."

The Evolved Expendable Launch Vehicle (EELV) program will also use a form of TSPR for sustaining the vehicles developed for launch of future spacecraft, including the infrastructure and sustainment processes and procedures to be used in meeting mission requirements. Hence, the deficiencies identified by the Air Force launch offices both at SMC and Det 9, while representing actual, current needs, may be resolved by the EELV TSPR approach selected and executed for future launch systems. The deficiencies are presented in this report to document the current needs as identified and perceived by the study team.

2.1 COMPARISON OF SPACE & AIRCRAFT SUSTAINMENT ACTIVITIES

2.1.1 Introduction

Policies and procedures at the wing and command level have been established by Air Force Space Command (AFSPC) to implement sound logistic support practices for the sustainment of space systems. For military space systems logistics, significant efforts have been expended in an attempt to use standard USAF air breathing and ground systems support policies and procedures. Most of these efforts have not been fully successful and as such, a unique logistics support system for space systems has not yet evolved.

2.1.2 Policy

Air Force policy for both aircraft and space systems have essentially the same readiness and availability requirements, that is based upon war criteria, engagement strategies, etc. that are common to both types of systems. Joint Vision 2010 applies across the board.

2.1.3 Operations

Operations for aircraft and space are very different, however. For aircraft, launch on demand equates to flying a wing of aircraft anywhere in the world in 24 hours, with capability to drop bombs on a target in 48 hours. The entire military infrastructure responds in unison to support this effort.

For space, launch on demand is not really attainable at this time because space systems are not as homogeneous as aircraft systems and their missions tend to be more unique and complex. Orbital assets are usually operating continuously with Space Control centralized at AFSPC centers. Users of information and/or data collected and down linked by space assets, operate and maintain their own hardware and software systems to meet individual mission requirements. The launch of satellites into their operational orbits is a separate and time intensive action that often includes lead times of several months and/or years. The operational readiness of space systems is dependent upon the space assets being positioned in the correct altitude, inclination

and orbit (satellites), and with ground systems fully functional and receiving downlinks with no anomalies to ensure operational availability in time of need.

2.1.4 Segments of Military Space Systems

Space systems are comprised of four basic segments: launch operations, space operations, spacecraft control, and user operations. This division of space operations among the segments complicates matters because they are often geographically separate from each other. Understanding, analyzing and planning logistics operations to sustain the mix systems and subsystems comprising each of the segments place heavy demands on logistics and maintenance planners and implementers. In this manner, space sustainment activities must cover a broad spectrum of independent elements and services that must be integrated, and work seamlessly together to provide essential support services to the space and terrestrial warfighters.

Military space systems exploit the full range of hardware, software, and firmware technologies at many orbital and terrestrial locations. Because each element bases its operations at different geographical locations, it drives organizational and intermediate levels of logistics support to evolve independently in order to sustain each segment's systems and subsystems' unique and peculiar needs.

2.1.4.1 Launch Segment

The Launch segments operate at Cape Canaveral Air Force Station (CCAFS), Florida, and Vandenberg AFB (VAFB), California. The logistics efforts for launch are focused on preparing vehicles and payloads for launch into orbit. Launch rates are fairly low at this time but are expected to increase as the next generation of launch vehicles, e.g. Evolved Expendable Launch Vehicles (EELV), becomes operational. Most expendable launch vehicles are currently used for maintaining constellation populations or for verification of new systems. Single pad facilities at VAFB and CCAFS for each type of expendable launch vehicle places severe limitations on current DoD launch capabilities to respond to a surge in launch requirements, or recovery from excessive pad damage.

When reusable transportation, such as the Reusable Launch Vehicle (RLV), becomes operational, VAFB and CCAFS will continue to be the prime areas for recovery, repair and recycling of the launch facilities and operations used in support of the RLV. NASA is the operator of the Space Shuttle, and is the government agency primarily responsible for the majority of payload processing and preparation activities for payloads delivered by the Shuttle. The USAF becomes involved during infrequent military shuttle payload preparation and recovery. While the shuttle is not an unreasonable model to consider, it must be noted that the payload integration and transportation functions have not been optimized for military use. The military needs rapid response, high readiness and maximum flexibility rather than optimizing single unit performance. For military use, optimum launch performance can be achieved through proliferation and a high launch rate. The optimum model for AF reusable launch vehicle operations can be viewed as equivalent to the C-17/ Abrams tank scenario; Load, fly, unload - - - move on to the next customer! Once such quick turn-around can be

achieved for satellite launch, the efficiencies and cost of space operations will invariably improve.

2.1.4.2 Spacecraft Operations and Control Segments

AFSPC spacecraft operations and control is centered at Colorado Springs with adjunct facilities at various locations to assure redundancy and survivability. The primary purpose of Spacecraft Operations is to provide products and services to the terrestrial warfighters, while Spacecraft Control is to maintain control of the orbital position and functional capabilities of the orbital assets. Both elements use basically the same equipment, primarily for communications and vehicle control, to perform their missions. Today's logistics support and sustainment operations are focused on maintaining the readiness of the terrestrial electronic equipment and software. Currently, the on-orbit spacecraft can only be supported by remote means, though up-linked commands and software changes. Since there is no means currently available to physically access or change-out failed equipment on the spacecraft that reach the end of life expectancy or fail, when such an event occurs, their function is terminated. At this point, they become effectively expendable or throwaway items. The timely and safe disposal of spacecraft is equally important to the space warfighters as they contribute to orbital debris and take up "Real Estate" (a valuable commodity), which are major space control issues.

2.1.4.3 User Equipment Segment

User equipment is much like other terrestrial systems and consists of electronic and mechanical equipment, both in fixed or mobile/transportable configurations. Typical user equipment consists of communicating devices, antennas, receivers, and computer workstations. The segment is also inclusive of computer peripherals, vans, shelters and comparable equipment. Some user equipment has fairly high populations, are deployed on a variety of ground, sea, and airborne platforms, and can be sustained by traditional two, three, or more levels of maintenance methods applicable to the using organization's respective services.

2.1.5 The Polymorphous Nature of Space Logistics

There are several aspects of space systems that work against a highly structured logistics support system. The acquisition, development and deployment process for space systems is a difficult environment for efficiently accomplishing logistics planning and implementation. The low equipment populations of spacecraft; the protracted development and operational periods; and the diversity of system elements required for operations tend to exasperate the typical Integrated Logistics Support (ILS) development process and individual ILS element processes. There is a tendency to accomplish space logistics planning and implementation on a piecemeal, and often "stovepipe" basis. Rigorous reliability analyses are not always accomplished early on to the level typically performed to identify failure modes and effects, and availability and maintainability analysis may be deferred, thus hindering actual logistics planning until late in the design and development process. Ground User systems are often distributed amongst multiple services and government agencies and each user supports and sustains its equipment differently. With the advent of the Total Systems Performance

Responsibility (TSPR) approach to sustaining space systems, the requirement to accomplish logistics support analysis to define support resource needs is further diluted since the responsibility for life cycle sustainment under TSPR becomes the responsibility of the developing contractor, not the government.

During the lifetime of space systems, the configurations of both space and ground-based hardware and software tend to constantly change. This is especially true in the space segment. For instance, if a system consists of a constellation of several spacecraft, in all probability each spacecraft will have slight differences in hardware and software due to the timeline between assembly and deployment, and the speed at which the state-of-the-art technologies change. There is also a corresponding ripple effect on design changes that take place within ground element configuration, again driven by the evolution in applicable technologies. Change is so prevalent that the terrestrial systems, with a few exceptions, tend to be supported much like R&D type systems with patches and workarounds rather than systemic configuration updates.

Spacecraft are usually maintained in a constant operational mode throughout their lifetime from orbital insertion and checkout, until end of life or failure. This limits possibilities for performing scheduled preventive maintenance and housekeeping activities, as there are very few other spacecraft that can be placed into service to temporarily perform the mission of the "down for maintenance" spacecraft. There is no "Flightline spare" of Reconnaissance, Communication or Transport "spacecraft" from which to choose if one unit is unavailable. Once a spacecraft is taken out of service for any reason capabilities are diminished until it can be placed back in service or replaced.

Due to the limitation of on-orbit spares, spacecraft are usually designed with extra capabilities so that if one is down in a constellation, there are sufficient capabilities embedded in the remaining spacecraft in the constellation to continue operations. Good examples of this are the low and medium orbiting communications and positioning satellite systems that are made up of constellations of several spacecraft. For those constellations with very few spacecraft, this "backup" capability is extremely limited, or non-existent.

2.1.6 Acquisition Logistics

The performance of acquisition logistics planning and management of space systems requires experience, understanding of space systems' support alternatives, and insight into the product support requirements, decisions and solutions applicable throughout a space systems life cycle from inception through deactivation. Due to the uniqueness of space systems as described above, life cycle planning for space systems sustainment has higher levels of uncertainty than for terrestrial systems. Because of the difficulty in accurately defining the support requirements for space systems, the tendency has been to defer logistics related decisions until the true operational nature of systems and equipment emerges. This, of course, raises the risk of systems being down for extended periods, and drives up the logistics support life cycle costs for those systems.

Deployment
Deploying space logistics support capabilities requires a mix of hardware, software, personnel, data, facilities and transportation. The logistic support of any space system has to be optimized for the specific type of equipment within each element in order to maintain the highest level of availability or readiness attainable. These logistics resources are deployed and used at various times and have different individual lifetimes. A space logistic support system is itself a "System of Systems". It may never come together in physical sense, is highly dependent on the performance and availability of each logistics element (e.g. spares, test and support equipment, tech data, etc.) to ensure and sustain the operational readiness of the space system.

2.1.7 Operations
Operating an effective logistics support program involves coordinating the activities of several resource and service providing organizations and systems. The USAF and other military forces focus effort on assuring that space systems can perform their mission, and be operationally available to meet mission needs at or close to 100.0% of the time. For aircraft flight operations, the proof of the logistics system effectiveness is in it's ability to provide the logistics resources when and where needed to ensure the required readiness levels of the squadrons are maintained to meet mission sortie rates.

For space operations the proof that their logistics system is working is multi-faceted and ingrained into each of the segments contribution to perform the space mission. For example, for each mission the controllers must determine if the satellites are in their correct orbital position and operating properly. If not, they must "fly" the satellite to the required position, and perform functional and operational tests to ensure all on-board systems are functioning within acceptable tolerances. The space warfighter must also determine that the control centers have communication and control over the satellites, and that the users have capability to communicate their needs, and receive the information they require to perform their missions. And finally, if a launch of a replacement satellite is required, the controller must determine if the launch systems are available to meet the launch schedule and windows for proper orbital insertion. Each of these space segments must be supported by the space logistics system if a space mission is to be successful.

Figures 4A and 4B provide a summary level description of several of the key differences in operating and logistically supporting space systems highlighting the some fundamental differences in the way space assets are operated and maintained.

Summary Level Comparison
Space - Aircraft Sustainment Operations

SUSTAINMENT FUNCTIONS	AIRCRAFT	SPACE SYSTEMS
Policies	Sustainment must support the same type of readiness and availability requirements	
Support Operations Launch on Demand	AFMC sustainment infrastructure designed for and responsive to requirements of the Air Force flying mission Capable of sustaining high sortie generation rates (Desert Storm)	<u>Launch</u> Not currently attainable for launch of space systems. Low launch rates. Dedicated launch sites per vehicle. <u>Space Operations</u> Orbital assets usually in continuous operations & controlled by AFSPC <u>Space Control and Users</u> Ground control sustained by AFMC, and contractors; Users provide own support assets
Assets Deployed	Usually fielded and deployed in large numbers. Ground support units co-deploy Aircraft may launch from multiple airfields	Spacecraft deployed in constellations of relatively few numbers. Space operations, control, and User legacy equipment geographically dispersed. Equipment acquired for specific space systems and often with unique characteristics (GPS user sets are an exception)
Acquisition Process	Plan and develop logistics support resources along with mission equipment for concurrent delivery to org. level and depot maintainers	Majority of support resources provided by contract (TSPR). Limited organic resources provided to support User equipment in the field

Figure 4A: Comparison of Space and Aircraft Sustainment

Summary Level Comparison
Space - Aircraft Sustainment Operations

SUSTAINMENT FUNCTIONS	AIRCRAFT	SPACE SYSTEMS
Logistics Resources Spares & components, Test and support equip, Tech data, Training equip, Maintenance Manpower PHS&T etc.	Large quantities acquired High degree of standardization and commonality Organic maintenance by operational units World-wide deployment and operations Recurring training requirements (pilots and maintainers) Mil Spec Tech Orders maintained by Depot Supported by Standard Base Supply System Supported by CAMS and REMIS AETC training for all ops and maint. AFSCs	Each space system is different: Few in numbers Selected User deployments Stovepipe support structures Minimum standardization High COTS equipment and data Contractor provided resources and sustainment services AETC training for space operators; selective upgrade training by contractors for USAF maintainers PHS&T tailored for each system
Configuration Control	Configuration Control rigorously maintained across the fleet.	Configuration control driven by technology upgrades/improvements Each spacecraft in a constellation may have slightly different configuration. Ground systems often upgraded to meet performance changes driven by spacecraft modifications/upgrades

Figure 4B: Comparison of Space and Aircraft Sustainment

2.1.8 Convergence of Space and Aircraft Support Concepts

With the advent of reusable space transportation (RLV), the nature of future military on-orbit systems can be postulated. It is expected when these capabilities are available spacecraft could be easily and frequently accessed by manned and robotic servicing systems to provide re-fueling of propulsion systems and mission expendables (i.e. Space Based Laser), and eventually to replace or upgrade satellite subsystems. To take optimum advantage of this eventuality, the military could conceivably restructure its current terrestrial space support operations by space basing selected maintenance and servicing capabilities. Organizational and intermediate support and sustaining levels could in fact be established on-orbit to repair/replace equipment and replenish expendables. Adoption and implementation of this concept will enable a change in the military space architecture from individual satellites to platform-based systems. Consolidating military space assets in this manner would save development and procurement costs on many levels and provides the space warfighter with increased flexibility in the employment of space resources. Space platforms could be more robust and might afford a capability to be more readily defended in a hostile scenario. When this concept becomes a reality, many of the terrestrial logistic support resources and processes applicable to generating aircraft sorties could be extrapolated and/or modified for space logistics application.

The Orbital Express Space Operations Architecture program currently underway by DARPA will develop and demonstrate robotic techniques for on-orbit preplanned electronics upgrade, refueling and reconfiguration of satellites that could support a broad range of future U.S. national security and commercial space programs. The demonstration spacecraft will be launched in 2004. An important element of the program is the enabling nature of such capability for new space missions and its potential to reduce space program costs through spacecraft life extension ("Pre Planned Product Improvement," or "P3I"), comparable to what is done today with aircraft.
The Air Force Space Battlelab is closely monitoring this experiment for potential application to Air Force space systems.

Ultimately establishment of a space logistics infrastructure could form the basis for most of the future military space systems. The Air Force Space Battlelab is assessing the potential application of on-orbit support techniques for future Air Force space systems. A recommendation is to be presented to the AFSPC General Officer Council during the fall 2001 for approval and initial implementation of this concept as a requirement in selected future Concept of Operations (CONOPS) documents for Air Force space systems.

It is envisioned that a space logistics infrastructure for sustaining United States space assets will evolve over time. Further, it is recognized that not all the elements of the infrastructure may be developed and implemented at the same time, or even by the same agency. An infrastructure of this nature will be at least national in scope and could be provided to support both military and civil space systems. It is clear that at this time, unless the Air Force makes a conscious decision to make such a capability a

requirement for future military space systems, such a vision for a space logistics infrastructure would take several decades to evolve.

2.2 DOD SPACE TECHNOLOGY GUIDE (STG) REVIEW

The 4 May 2000 draft document of the DoD Space Technology Guide (STG) was reviewed by the study team for correlation of technology requirements development projects suggested in the document, to candidate logistics research projects derived and identified in the DO 12 AFRL Space Log Front End Analysis Study. When completed, this DoD STG will be a publication issued by the Office of the Secretary of Defense. The document describes the need, i.e., technology "pull" or "demand" to match the technology "rush" or "supply" provided both by U. S. Government agencies and by commercial interests worldwide. The details of the STG review are contained in Appendix B.

2.2.1 Conclusions from the STG Review

Air Force missions will change over the 2000 through 2020 time period, and logistics operations, processes, and techniques must keep pace.

Space logistics technologies suggested in the STG document, and separately by the writers, could facilitate major steps forward in their own areas and thereby provide leverage to one or more other areas – to the point where revolutionary advances in space capabilities, performance and operations may result.

For the long term, the Air Force's pursuit of the several classes of Microsat, from Smallsats down is geared toward the achievement of new capabilities leading to new operational paradigms; i.e., the Microsat "vision' is for combinations of characteristics and capabilities that will enable new "ways of doing business" operationally. New and innovative space logistics systems will be required to support this premise.

Approximately 50 technologies were identified in this report as having application to space logistics requirements; however, not all are equal in their importance to AFRL/HESS research goals. Resources and priorities are always considerations. However, it is suggested that the 50 technologies could be distilled down to the following core list of five space logistics technologies presented in no order of priority.

1. **Data Management and Encrypted Information Processing.** Includes: inventory control, real-time combat damage assessment, on-orbit mission control, modeling and simulation tools, space-based internet access and terrestrial network, continuous status reporting, automated vulnerability assessment, multi-level security systems and survivability assessment systems.

2. **Mobile, High Precision Aerospace Ground Equipment (AGE).** Includes: carts, modules and trailers that can be configured to any spacecraft or launch vehicle for payload to launch vehicle integration and launch site space system

processing, launch vehicle loading and recovery, check-out for launch ready, and non-intrusive testing.

3. Probatic Systems. Includes: adaptive, all-weather self-training devices for hazardous material handling, payload optics decontamination; cryogen handling, modules exchange, on-orbit resupply concepts, and ability to reconstitute and repair asset systems on orbit.

4. Human Factors. Includes: user friendly logistics decision support tools (i.e. LDST) and protocols, human-computer interfaces, vertical reality of technical data, area training courses and equipment, allocation of human resources, human centered automated test-bed for check-out of new procedures and intelligent tutoring.

5. Standardized Interchangeable Software, Electrical, Mechanical, Thermal, and Fluids Interfaces. Includes: Autonomous rendezvous and docking systems, fluid couplings, C3 practices, data distribution codes and addresses, and training procedures.

2.3 AFRL/HESS RESEARCH RELATED TO SPACE LOGISTICS

There are certain developments that the Deployment and Sustainment Division have done in the past or are currently undertaking that lends themselves to applications in space. To focus the search for relevant military space support technology areas that AFRL/HESS could develop, in the near term, a list of potential bridges from past or existing work is pertinent to this study.

The bridge material should be useful for developing future space logistics research concepts. The activities shown below are good starting points to look at for research opportunities that AFRL/HESS can accomplish with a little stretch in support of space activities. This list is not meant to be limiting in any way but rather serve as a catalyst for exploring research areas.

Listed below are several areas of past and current AFRL/HESS logistics research. Under each is a list of potential space logistics applications.

AEROSPACE GROUND EQUIPMENT STANDARDIZATION & OPERATIONS

- Payload and Vehicle AGE Modularity Concepts
- Launch Site Equipment
- Flight Support Equipment
- Servicing Equipment
- Mobile Mission Processing Equipment

DAMAGE ASSESSMENT AND REPAIR

- Pre-launch Maintenance
- Launch Processing

- Payload Processing
- Operational Maintenance and Servicing Management
- Cognitive and Neural Science Telerobotics
- Post Landing (return from space) Processing

LOGISTICS READINESS OF ASSETS

- Intelligent Agent assistance of data assimilation for status visibility
- Advanced UI concepts for presentation of assimilated readiness data
- Proactive Decision Support tools at Wing level and drill down view
- Information fusion from disparate databases

AIRCRAFT MAINTENANCE AT POINT OF ORIGIN

- Interactive Electronic Technical manual access at point of origin
- Means of viewing aircraft status at the flightline
- RF capabilities, Bar-coding and Mobile Units Technologies

AUTOMATED TECHNICAL ORDER GENERATION

- Payload and Launch Vehicle Processing Procedures
- Integration and Checkout Procedures Mission Assurance Procedures

VIRTUAL REALITY

- Virtual Reality Benchmark for Launch Practice
- Evaluate Potential Standard Practices
- Automated Interpolation and Extrapolation of Potential Improved Processes
- Deviation Trend Monitoring and Analysis
- Test Performance Data Capture
- Speed up Verification of Remedial Procedures
- Resource Usage Estimates and Monitoring
- Battle Lab Operations, Maintenance and Servicing
- Procedures Involving Computer Sciences (Virtual Environments)

HUMAN FACTORS

- Modeling Math Analysis and Simulation
- Information Systems Technology (Human/Computer I/F)
- Common Protocols for Maintenance & Repair Tasks
- Diagnostic and Repair Tech (Quick-Look Test Instructions)
- Human-Centered Automated Test Bed

3.0 LOGISTICS REQUIREMENTS FOR SPACE SYSTEMS

In our research and analysis, it was evident that space logistics/sustainability technology needs have not been specifically defined in using or sustaining command Mission Area Plans (MAPs) and Technical Planning Integrated Product Teams (TPIPTs). However, the team noted that the Space Technology Guide (STG) is the most comprehensively documented compendium of space logistics/ sustainment needs that exists at this time, within the Air Force.

During the team interviews and follow-on discussions with the space system acquisition and sustainment personnel, the dialogue successfully surfaced several sustainment issues and requirements that exist. However, it should be noted that the team identified "requirements" and "deficiencies" during the interviews extracting relevant information through the use of "what if" type conversations with space system developers, operators, and sustainers. For example, the team found that space operators and maintainers do not usually define classic deficiencies in space sustainment. These agencies (and their personnel) work within current processes, equipment, and software, until they attain the required levels of readiness for space related systems. Since the space and launch elements of space systems have low populations and are often only a few steps removed from an R&D configuration, in many cases they are pretty close to the state-of-the-art in regard to level of technologies used. Support resources often lag the operational hardware as far as technology and operability are concerned

The transition of space systems launch, operations and sustainment to contractor provided services has essentially blunted many user priorities and needs for updating logistics support technologies associated with space systems. The concern found by the team was that since the existing support systems "won't be around too much longer" that there would be insufficient return on any investment made in improvements in the support area. The concern expressed with this approach is that there haven't been sufficiently strong sustainment provisions stipulated in the Operations and Maintenance (O&M) contracts for commercial services; consequently, there are no decent models available for sustainment of current systems for contractors to emulate.

Space logistics requirements were developed by the team through execution of the process shown in Figure 5. The process started with preparation of a logistics parameter matrix for the time period of year 2001 to 2010. This matrix consisted of a series of charts and tables showing time-phased space payload numbers for payload type, customer, region, mass, orbital location, prime contractor, launch vehicle/launch site, mission control centers, and user traffic. Inputs to this matrix reflect the Air Force roles and goals in a changing geopolitical environment and their expected mission objectives for the above time period. Also input to the matrix was information obtained from our Contact Plan interviews; the Air Force project office (AFRL/HESS); the Teal Group; commercial logistics practices; the AFRL "Logistics Requirements for Space

Phase 1 Report"; Lightning Bolt 99-7; information contained in the DoD Space Technology Guide (April 2000); and the lifetime experiences of the team members.

Criteria established by the team for selecting the logistics requirements included the following: Must be quantifiable, defendable, insure safety and sustainment of space systems, and be affordable to implement. In addition, the selected requirements must recognize the maturity and availability of technology and equipment, operational dependability, "do-ability" with cost-effective development, and be supported by operators/user needs.

Figure 5, illustrates how the study team categorized the requirements into mission, system, and interface classes and time phased them as appropriate into the near and far term time periods. Mission requirements pertain to techniques; system requirements to hardware or software; and interface requirements to the functions and interdependencies that exist between the four segments, launch activities, space operations, control functions, and user disposition of the data acquired from space.

Following the development of selected and allocated logistics requirements, we assessed the technology projects needed to enable or enhance the development of specific requirements that are not currently operational. From this technology assessment, we generated a set of AFRL/HESS logistics research concepts.

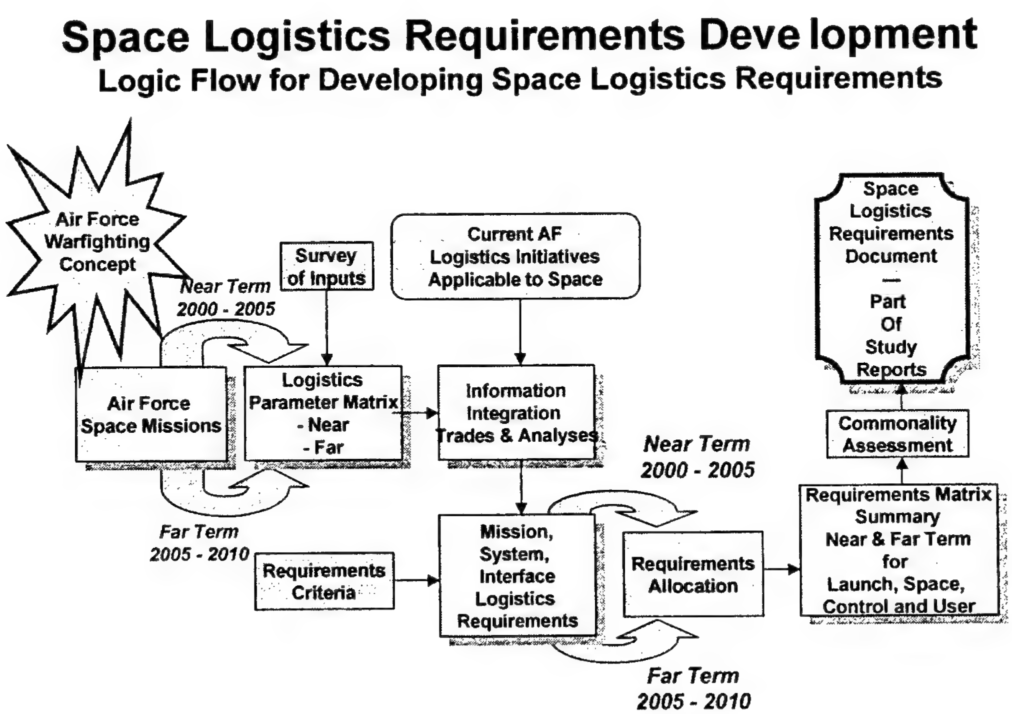

Figure 5: Logistics Requirements Development

3.1 CURRENT AIR FORCE PROGRAMS

Acquisition and sustainment space logistics requirements for current Air Force programs were derived by analyzing the system deficiencies and technologies obtained through the execution of our Contact Plan. These deficiencies and technologies are described in Sections 5.0 and 6.0 of this report. The current Air Force programs included in the study team's assessment is included in Table 1 and Table 2.

Table 1: Operational Launch Vehicles

Name	Description	Performance Characteristics
Atlas (LM)	An expendable, medium-lift launch vehicle operated by AFSPC. Three Atlas flights are scheduled for FY01 and three in FY02 from CCAFS, Florida and VAFB, California.	19050 lbs to LEO from CCAFB, Atlas II AS 4900 - 8150 lbs to GTO from CCAFB, Atlas IIIS 13650 -15900 lb to LEO from VAFB, Atlas III S Up to 9920 lbs to GTO from CCAFB, Atlas III A
Delta (Boeing)	An expendable medium-lift launch vehicle operated by AFSPC. Four Delta flights scheduled in FY01 and four in FY02 from CCAFS, Florida and VAFB, California	Up to 11,100 lbs to LEO, Delta II Up to 4010 lbs to GTO, Delta II Up to 2000 lbs t, Delta II Up to 8930 lbs to GTO, Delta III Up to 18280 lbs to LEO, Delta III
Centaur Upper Stage (LM)	A high-energy upper stage with multi-burn and extended coast capability operated by AFSPC. Developed by LM	Performance characteristics unavailable
Titan (LM)	An expendable, modified ICBM used to launch military, classified, and NASA payloads, operated by AFSPC. One launch scheduled in FY01 and none in FY02 from VAFB. Developed by LM	More than 4200 lbs to polar LEO
Titan IV (LM)	An expendable heavy-lift space launch vehicle to carry DoD payloads into space, operated by AFSPC. Developed by LM	32000 lbs to polar LEO, Titan IV A 39000 lbs to LEO, Titan IV A 10200 lbs to GEO, Titan IV A with Centaur G 5200 lbs to GEO, Titan IV A with IUS
Evolved Expendable Launch Vehicle (LM/Boeing)	A medium/heavy expendable launch vehicle operated by AFSPC. First launch scheduled for medium heavy FY02. Contractor is Boeing (Delta IV) and LM (Atlas V).	(medium) 9200 lbs to GEO, Delta IV (heavy) 29000 lbs to GEO, Delta IV (medium) 18900 lbs to LEO, Atlas V (heavy) 42000 lbs to LEO, Atlas V
Pegasus (Orbital Sciences/Alliant).	An expendable, small winged launcher to carry small payload to LEO.	850 to 1050 lbs to LEO
Taurus (Orbital Sciences)	A small, expendable, ground-launched launch vehicle for use in testing a quick-readiness, mobile launch facility. Operated by AFSPC for DoD payloads.	3000 lbs to LEO 800 lbs to GEO using a Star 37 perigee motor
Minotaur (Unknown)	A low cost, expendable, ground-based launch vehicle tasked to deliver small satellites into orbit. Operated by AFSPC for DoD payloads.	Up to 750 lbs to LEO. Two successful launches in 2000.

Table 2: Operational Satellite Systems

Name	Description	Performance Characteristics
Defense Meteorological Satellite Program (DMSP)	An environmental monitoring satellite that collect air, land, sea, and space environmental data. Operated by NPOESS Contractor: Lockheed Martin	2 satellites at 500 miles Weight: 1750 lbs
Defense Satellite Communications System (DSCS) Contractor: LM	A communications satellite to transmit SHF high priority C^2. Operated by AFSPC.	5 satellites in GEO Weight: 2580 to 2716 lbs
Defense Support Program System (DSP) Contractor: TRW, Aerojet	An early warning spacecraft. Provides alert of possible ballistic missile attack on U.S. forces or homeland. Operated by AFSPC. Last DSP will be launched in FY03.	Constellation: Classified at GEO Weight: Approximately 5000 lbs
Global Positioning System (GPS) Contractor: Boeing and LM	Provides navigation data, 24 hour/day, to military and civilian users. Operated by AFSPC.	Constellation: 24 satellites at 12636 miles. Orbit earth every 12 hours. Weight: 2174 lbs (IIA), 2370 lbs (IIR)
Milstar Satellite Communications System Contractor: LM	a satellite communications system that provides secure, jam-resistant, worldwide C^2 for tactical and strategic forces in all levels of conflict. Links command authority to ground forces, ships, subs, and aircraft. Operated by AFSPC.	Constellation: 3 satellites (with 3 spares) at GEO Weight: 10000 lbs
Milsatcom Polar System Contractor: Classified	provides secure, survivable communications, supporting peacetime, contingency, and wartime operations in the North Polar region. Operated by AFSPC.	Constellation: 3 satellites at GEO Weight: 470 lbs (payload)

3.2 GROUND-BASED SERVICING REQUIREMENTS

A unique logistics support infrastructure is needed to support current ground based servicing operations for space-based assets. This infrastructure must contain the following logistics resources and capabilities to respond to operational failures or anomalies experienced either by the ground segment equipment, or space-based assets: spares, consumables, support equipment, maintenance procedures, trained personnel, and reliable, available on-demand launch capability.

Typical ground-based satellite servicing technologies that need to be developed and maintained for sustainment of future space systems are accurate and rapid fault

isolation and detection, rapid payload integration and launch processing, and complementary flight support equipment to conduct in-situ servicing and repair operations. Robotic servicing equipment used for in-situ sustainment support will also require preventive and corrective maintenance, and protective storage facilities to be available to support mission operations quickly and reliably. These maintenance and/or servicing actions will most likely be performed with the operational spacecraft in its normal orbit and could be considered comparable to flightline maintenance of aircraft.

3.3 FUTURE AIR FORCE PROGRAMS

This study emphasized the logistics deficiencies and requirements for current Air Force space systems. However, a cursory review was made of future Air Force programs in order to consider and intelligently transition logistics technologies from the present to the near term space activities of interest to AFRL. This review can be found in Appendix C.

3.4 SPACE PAYLOADS TRAFFIC MODEL

Comprehensive analysis of space logistics covers a broad range of system engineering topics; from generating: ground and space based payload traffic models, workable simulation programs, and proof-of-concept demonstrations to verification of newly developed logistics decision support tools.

This section addresses space payloads traffic models. Payloads, or satellites, are the only Air Force operational systems where no post deployment repair, maintenance or upgrade capability is routinely provided. The result is expensive space systems and high cost of transportation to space. A description of the findings of this review can be found in Appendix D.

SUMMARY

The Air Force will deploy only about 8% of the space payloads from 2000 through 2009 (165 out of 2147). However, due to their unique flexible sustainment requirements associated with: precision engagement, rapid global mobility, agile combat support, and information superiority, their logistics systems will be the standards to which other agencies (U.S. and international) will be compared.

The Payloads Traffic mode - embodied in the discussed 5 topics - must be updated yearly so that the Air Force logistics managers will have a numerical basis from which to develop logistics tools and techniques necessary to keep their sustainment policies current and effective.

The payloads traffic model will also help in Air Force decisions to co-share logistics storage, launch, control, and operational equipment with other U.S. or international agencies.

4.0 LOGISTICS SYSTEM DEFICIENCIES

The AFRL/HESS Space Sustainment Study placed primary emphasis on obtaining relevant logistics deficiencies and requirements from the user and sustainer organizations. The government and support contractors interviewed identified existing deficiencies that were often recognized by their respective organizations. Additional deficiencies were identified as needed improvements that would greatly benefit the sustainment of the space segments for which their organization or office has support responsibilities. These sources and the deficiencies are listed in Appendix A.

4.1 SPACE LOGISTICS GOALS

To focus the study in defining deficiencies that impact the operational space forces, the team examined the overarching sustainment goals established for the space warfighting missions. These USSPACECOM goals are published annually and focus on three key areas: (1) Increase Support to Warfighting CINCs; (2) Provide focus and leadership for future space capabilities; and (3) Improve operational effectiveness and efficiency, commensurate with the overall command goals. DoD logistics goals focus on increasing availability of war-critical assets while reducing life cycle cost. The three principal logistics goals for the Air Force warfighting and sustainment commands include the following:

- Reduce Logistics Response Times
- Develop Seamless Logistics Systems
- Streamline the Logistics Infrastructure

These goals were the principal focus of the study team's collection of deficiencies that could benefit from AFRL/HESS research and technology development/improvements:

4.2 DEFICIENCY ANALYSIS

The deficiencies collected from user organization personnel were initially listed under the headings of: Acquisition and Sustainment Logistics. They were subsequently allocated to the functional categories of <u>technical</u>, <u>process</u>, and <u>management</u>. A few of the collected deficiency statements were deemed to be general or administrative in nature – and were labeled as <u>comments</u>. No interview or survey information gathered during the surveys was discarded or ignored during the analysis. The total number of deficiencies collected by the study team survey is characterized as follows:

- Technical Deficiencies 35
- Process Deficiencies 21
- Management Deficiencies 13
- Comments <u>11</u>
- **TOTAL** **80**

These 80 deficiencies and corresponding comments, shown in Appendix A-4, were the basis of further analysis to define current logistics requirements and technology needs.

An issue was considered a deficiency if it can be corrected by machine, device, equipment, or by implementing an improved procedure, command, directive, personnel change, or application of additional training. A deficiency issue was given additional consideration by the study team if it was identified by more than one interviewee, applies to a near term 2002-2005 problem, and impacts more than one user, organization, or program. From an analysis of the survey findings, it was concluded that a fine line exists between technical and procedural deficiencies and management problems. For example, sometimes a deficiency will be rectified by a management decision but will require application of considerable technology to be successfully accomplished.

To provide a means to clearly describe and distinguish differences in the survey findings, the study team derived the following definitions to facilitate the analysis process:
Technical deficiency is one that can be corrected by hardware or software.
Procedure deficiency is one solved by a model, sequence or protocol change, new data processing system, different/improved training, manpower assignments, schedule revision, input/output revisions, or insertion of different criteria.
Management problem is one fixed by a command, directive, order, or revision of requirements or criteria for success.

The team concluded that actual differences between technical, procedural, and management deficiencies are oftentimes very small. There were cases where an issue was declared to be a management item but required an extra degree of technology support to actually correct the deficiency.

Most of the deficiencies or comments came directly from the representative of the organization contacted, however, several were derived through analysis of the acquired information.

Deficiency Analysis Details – The study team separated the 35 technical deficiencies into 10 broad technology areas and then determined what specific enabling technology applications would be required to be applied or developed to permit the Air Force to meet the logistics need implied in the deficiency. The 10 technology areas include:

1. Data generation
2. Environmental control
3. Facilities`
4. Simulation and training
5. Aerospace ground equipment
6. Inspection and damage assessment
7. Launch vehicle payload integration
8. Telemetry
9. Microsat processing
10. General

4.2.1 Technical Deficiencies

The 35 space logistics technical deficiencies noted by the study team were separated into 10 categories. This section identifies the proposed developing or enabling technologies required for correcting the deficiencies.

1. *DATA GENERATION* – The deficiencies herein pertain to logistics databases for acquisition and sustainment activities:
   - Must be able to mine all available data bases
   - Maintain technical order currency
   - Model partial data
   - Effectively use encrypted data management and information processing, and
   - Have access to automated, secure data

A model "wizard" support system was also identified as a need.

The related ENABLING TECHNOLOGIES include:

- Information processing
- Human factors
- Advanced tools and algorithms
- Encryption
- Computer graphics
- Data fusion with multi-level security
- Computer programming

2. *ENVIRONMENTAL CONTROL* – The deficiencies for this category related to:
   - Personnel and hardware protection and reduction from environmental hazards
   - Need for a derivative of the standard DSP type mobile control system
   - Ability to detect a space environmental hazards (data transmitted to ground)

The associated ENABLING TECHNOLOGIES include:

- Integrated sensors/control systems
- Heating and air conditioning
- Human factors

3. *FACILITIES* – Most of the deficiencies suggested in this category relate to the launch sites – for the most part VAFB. Suggestions were made that any new sites be designed for a 30-year life and that the present launch pads be convertible to allow rapid conversion for commercial launches. The deficiencies for this category related to:
   - Safety factors
   - Launch site restoration following launches
   - Damage assessment
   - Personnel training

The associated ENABLING TECHNOLOGIES include:

- Construction
- Environmental impact technologies
- Access and security
- Geology and seismology
- Civil engineering
- Radiation hardening
- Human factors

4. *SIMULATION AND TRAINING* - The principal deficiency identified to the study team in this area was related to the need for a crew training simulator for the SBIRS program. The deficiencies for this category related to:
   - Modeling and simulation procedures
   - Need for intelligent tutoring devices

The associated ENABLING TECHNOLOGIES include:

- Virtual reality
- Digital electronics
- Data processing
- Display and controls
- Software management
- Automated reasoning
- Neural networks

5. *AEROSPACE GROUND EQUIPMENT* – Interviewees at VAFB contributed most of the deficiency comments for this category. The deficiencies for this category related to:
   - Mobile high precision AGE
   - Lack of a universal propellant loading system that could be used at more than one launch site for a variety of launch vehicles
   - Lack of sufficient and safe ground based cryogenics handling and storage equipment

The ENABLING TECHNOLOGIES for this category are:

- Mechanical engineering
- Electronics
- Fluid mechanics
- Propellant tanks for Cryogenic fuels
- Human factors

6. *INSPECTION AND DAMAGE ASSESSMENT* - A number of deficiencies were identified to the study team in this category including:

- Need for remote inspection of launch vehicle and satellite surfaces while the space system was on the launch pad. This was especially true in the final stages of the countdown
- Related to this was a need for advanced diagnostics with data transmitted to control stations
- Non-intrusive inspection
- Optics decontamination
- Quick change of damage structures
- Software to prioritize launch site damage

The ENABLING TECHNOLOGIES for this category include:

- Sensors
- Robotics
- Electronics
- Instrumentation
- Displays
- Various detector devices

7. *LAUNCH VEHICLE PAYLOAD INTEGRATION* – Stated deficiencies in this category were identified as:
   - High density interconnected electronics
   - Quick optics change-out on the launch pad
   - Lubrication of critical joints
   - Detection of hot spots on or near sensitive areas of the launch vehicle and its satellite payload
   - Detection of gas and fluid leaks from either the launch vehicle or the satellite payload

The ENABLING TECHNOLOGIES applied to this category include:

- Robotics
- Sensors and displays
- Modular optics
- Calibration and testing
- Integrated situation assessment tools
- Self aware/healing networks

8. *TELEMETRY* – Considerable discussion with VAFB interviewees resulted in the following deficiencies cited for this area:
   - Need for tracking anomalies via telemetry
   - Need to place on board the launch vehicle and the payload a data recorder with information transmitted to ground terminals. This is to monitor and record vehicles launch performance prior to lift off and subsequently tracked during assent flight with information constantly transmitted to the ground

The ENABLING TECHNOLOGIES in this category include:

- Instrumentation
- Communications
- Sensors
- On board data processing
- Secure transmission systems

9. *MICROSAT PROCESSING* – Deficiencies in this category was proceeded by discussions with the interviewees regarding the Air Force's potential use of future of microsatellite systems. The consensus among the user personnel interviewed was that when Microsats became part of the Air Force's operational strategies, the processing of Microsats at the launch site would drive changes in space sustainment logistics and infrastructure requirements. Specialized technologies and techniques will need to be developed for launch site Microsat processing.

The ENABLING TECHNOLOGIES for this application include:

- Microelectronics
- Unique data management, scalable/fault tolerance computer programming
- Data base systems to accommodate a variety of Microsat configurations
- Inventory control procedures updated to accommodate launch on demand operations

10. *GENERAL* – This category was included to identify at a summary level many of the deficiencies cited by the interviewees, and noted in the materials researched by the study team for predictive, on-condition, and preventative maintenance interfaces that did not fall within the technical definitions of the preceding nine categories.

The ENABLING TECHNOLOGIES in this general area were related to logistics planning, sustainment engineering, facilities development, training, and special aerospace ground equipment.

4.2.2 Management Deficiencies

The 13 management deficiencies or issues are listed below under four categories. A brief description of each is given.

1. NETWORKING

- Acquisition logistics or sustainment personnel are not in all cases active participants during the start up phases of a new program
- A virtual office tool is needed to enable all users to keep track of program status
- Output products are not always aligned with the acquisition process. All activities and products must clearly be identified
- Sustainment personnel are not always able to obtain maintenance data on TSPR contracts

2. DECISION PROCESSES

- Capability not always available to justify and defend the decision process used in development and approval of a support concept that may not be compliant with the DoD 50/50 rule and other requirements
- Acquisition logistics personnel sometimes fail to adequately consider the back end of a program life cycle and sustainment activities early in the planning process, or consider them inaccurately – including costs

3. OPERATIONS

- VAFB Det 9 in addition to <u>identification</u> of risk management issues and problems may be required to <u>perform</u> risk management tasks. The organization responsible for risk management will be dependant upon who is responsible for successful delivery of payloads to orbit
- Other services maintenance data is not always available to USAF; therefore, performance of failure analysis for non-USAF user systems often cannot be performed
- The continuously changing configurations of the new generation spacecraft and ground elements continues to be a primary challenge to the sustainment community
- Two pads at each site could provide for launch emergency back up, security, and concurrent launching of military and commercial (foreign) payloads. However, redundant launch pads are not currently planned for VAFB
- There is a big deficiency in the amount of quality control activity accomplished prior to the launch vehicle and payload delivery to VAFB
- VAFB may be required to perform launch-on-demand to support certain National Reconnaissance Office payloads

4. COST INFORMATION

- Business model is needed to that could provide access to current labor costs for government grades and ranks, and contractor labor rates

4.2.3 Procedural Deficiencies

Twenty-one designated Logistics Procedural Deficiencies identified by the study team are listed below in eight categories. Generally, issues in these categories will require management decisions, or changes in the process flow to achieve resolution. Some of the issues cited below are tied to computer modeling or matrix analysis.

1. SECURITY
   - Data already in models or in a process to be included into models are not always secure

2. DATA MANAGEMENT
   - Data acquisition for provisioning computation for the appropriate space system and its electronics
   - Maintaining models current with schedule and flight configuration
   - Labeling of configuration management data
   - Maintaining technical orders for legacy equipment
   - No central database to provide visibility and status over all sustainment resources

3. SCHEDULE
   - Insure all logistics tasks in both the acquisition and sustainment phases are accomplished in accordance with the program schedule

4. FACILITIES
   - Disposition of the VAFB launch pads that will be deactivated as a result of phase out of the Titan, Delta, and Atlas launch vehicle programs
   - Planning and preparation for EELV launches. Problems related to base support, housekeeping, safety, and security

5. OPERATIONS
   - Future EELV launches must show a lower launch cost than the present "Fly-out" systems
   - Currently there are no standards for commonality functions between launch vehicles, their assigned launch pads, support equipment, or processing methods
   - First, Second, and Third Space Launch Squadrons use three different maintenance data collection systems
   - Mechanical and electrical equipment and processes for corrosion control is deficient
   - Need common protocols for maintenance and repair across all systems
   - Need logistics support of information warfare operations
   - Special case microsat payload integration and launch site processing
   - Need ground logistics support architecture to accommodate satellite cluster configurations that can easily be changed to perform a variety of military missions
   - The integration process could be shortened if the launch vehicle and payload were integrated horizontally. This horizontal integration is not planned for EELV

6. ADMINISTRATION
   - Deficiencies exist in many launch-processing procedures for the current and EELV launches. A new set of processing procedures is needed to meet the VAFB goal of limiting payloads on the launch pads to no more than 7 days

7. MODELING
   - Need updated set of models for maintenance and repair protocols across all programs

8. MICROSATS
   - New launch readiness concepts needed for microsats formation flying and constellation missions

4.2.4 Survey Comments

The eleven comments presented below were obtained from the study team interviews and are repeated practically verbatim to preserve their integrity and meaning. They are general in nature and directed at Air Force management for further (if any) action. The study team is almost certain that AFSPC and AFMC command levels are aware of the content and background of each comment. It is the opinion of the team that for the most part, the comments do not lend themselves to resolution by specific technology application.

1. New acquisitions do not always recognize to 50/50 line and title 10 requirements. This should be done up front and accept the potential impact to logistics sustainment costs.
2. Need more influence on the support concept and how it's developed during acquisition.
3. When new acquisitions are programmed, 3400 money is not always considered in the decision process, consequently they are always playing catch up.
4. Logistics decisions are driven by launch readiness requirements, training requirements, and the schedule; not so much technology enhancements.
5. The deficiencies between leased and licensed facilities and properties have caused a whole new set of contract problems that involve acquisition logistics.
6. There may be proprietary software problems in several areas.
7. SMC/ CL has no basic plan or formula for performing their logistics work.
8. A deficiency is the defining and sustaining commonality between organizations and services as pertains to the terminal staffing and operation.
9. The sustainment functions include configuration management of the launch vehicle, interface control, and launch vehicles/satellite interconnects.
10. Different programs (Titan, Delta, and Atlas) implement their work breakdown structures to different levels. There is no correlation of time on the launch pad, launch costs, and integration procedures across various programs. Every launch is time and materials driven. Little change in this situation is planned for the EELV.
11. VAFB leadership needs to mature the concept that contractor actions are tracked to focus programs management on the systems engineering process and to implement quickly and economically corrective actions that are instituted as a result of launch system failures.

5.0 LOGISTICS RESEARCH CONCEPTS

The concepts that are recommended in this study were derived from the extensive data gathering effort at Air Force operating, acquisition and research organizations, as discussed in the previous sections. The selection criteria are based on the highest value to improving space sustainment. Technologies that are evolving were examined for application and those that fit the evaluation factors for 6.3-funded research and development were selected. The following section shows the process that was used to arrive at the final recommendations.

It should be recognized that the items mentioned below by and large were not simply stated by the canvassed organizations but were derived by careful analysis and validating of their needs, then comparing them with the capabilities and interests of AFRL/HESS.

The criteria for selecting an item to be an AFRL/HESS Logistics Research Project were developed jointly by the study team, AFRL, and AFSMC representatives and are identified below:

1. The item is an enhancement to space systems logistics or sustainment
2. Meets one or more logistics needs for a space system or user organization (look for multiple user needs)
3. The subject fits the AFRL:/HESS 2002-05 mission
4. The technology development candidate shows reasonable return for investment and risk reduction
5. The project has a technology readiness such that the development can be started in the reasonable near term
6. The concept is not a duplicate of other AFRL or other government research projects
7. Lends its self to affordable proof-of-concept lab tests and operational demonstrations, and is within the AFRL/HESS funding for research projects (about $1M per project per year)
8. Can be a joint research program with other agencies (i.e. NASA, NRO, DARPA, or NRL) where feasible for cost sharing
9. Application of the research project has potential benefit for application to down stream space projects and logistics infrastructure improvements
10. The research project is safe to conduct

A list of topics evolved that addressed the users needs in the area of sustainment. The team then compared these requirements with the capabilities and interest areas applicable to the AFRL/HESS mission. The descriptions below were the first cut at these concepts sequenced generally in the order of discovery.

1. Standardized Environmental Control Unit (ECU) Core Module

Space user terminals that are currently out in the field are from many sources and are of differing vintages and different states of the art. The ECUs are usually

relatively high maintenance items as their duty cycles are as high as any equipment in these terminals. With the proliferation of ECUs and the myriad of types, there is a substantial logistics effort involved in supporting these items in military systems. ECUs are normally lumped with institutional equipment so are often supported within the government maintenance and supply systems well beyond their availability on the civilian market.

2. SBIRS Crew Simulator

The logistics component of the SBIRS-Low SPO has indicated a deficiency is the quality of their ground operations control and data acquisition consoles. A new crew console Flight Training Device (FTD) is needed with up to 6 stations to provide simultaneous training for 6 operators. The FTD should be capable of cross training so that an operator will be trained to man anyone of the six stations.

3. Standardized Propellant Carts

There are different approaches and equipment for propellant loading for each spacecraft and launch vehicles at each launch site at VAFB and CCAFS. With the consolidation of launch vehicles and the trend toward contractor services there is an opportunity for the government to standardize approaches and equipment for more efficient launch preparation and operations.

4. Remote Inspection of Surfaces

Spacecraft, launch vehicles, and payloads are enclosed with surface structure critical to the configuration integrity, protection, and operation of the space system. It is important that the surfaces be inspected on a periodic time schedule and after an accidental event to determine any distortion or damage. This inspection process is important during the integration and test phase and vital during the launch phase.

5. Launch Readiness Assessment Tool

Several contractors use advanced diagnostic techniques to monitor the progress of their launch systems through production and preparation activities. The government has lost oversight capabilities in the transition process. The government needs a diagnostic system that can operate on existing testing data to monitor the readiness of the launch system before they commit their payloads to launch

6. Optics Decontamination Prior to Launch Following Payload Integration

Some Air Force spacecraft in the mission area of Intelligence, Surveillance, and Reconnaissance (ISR) have a considerable amount of critical optical surfaces that must remain free of contamination as the spacecraft goes through integration, test, and launch site processing. These surfaces are most vulnerable after payload integration with the launch vehicle out at the launch pad. The stated deficiency is having quick, efficient ways to perform optics decontamination without destacking. Contamination can come from environment conditions as well as from man-induced activities.

7. Leaks and Hot Spot Detection

When a fluid leak or a hot spot is discovered on the spacecraft or launch vehicle deep into the countdown there is no reliable device to quickly identify the leaking fluid (liquid or gas) and to pinpoint its location. There have been some 16 fluid types, liquids and gases, identified that are used on spacecraft and launch vehicles. In like manner no thermal measurement instrument is available to measure the magnitude and the location of hot spots on the launch vehicle or its spacecraft payload.

8. Enhanced Data Acquisition System for ELVs

A common concern voiced by several groups at SMC, AFSPC and VAFB was the inability of the Air Force to be able to verify the things like flight integrity and flight performance within the context of increased contractor provided launch services and the EELV. Contract provisions for these services allow access to, but not analysis of preflight and post flight performance data. This situation impedes the government's ability to anticipate impending failures, ascertain the margins that were realized during any particular launch operation and institute failure preventative measures.

9. Microsat Launch Site Processing

Microsat Launch concepts as depicted in the DoD Space Technology Guide Appendix G, have not been developed enough to demonstrate a real understanding of the nuances of launch operations and sustaining space operations. Microsats must still attain orbital velocities and anti-satellite (ASAT) trajectories and vehicles do not readily provide that kind of performance. Efficient launch approaches and procedures have to be developed to assure that these spacecraft are cost effective.

10. Ground Support Logistics - Satellite Clusters and Constellations

There are current and planned long duration military space systems that are constellations of large and small satellites. There are also many ground systems that make up part of these systems for the control and user functions of these systems. Sustainment activities for these systems are usually centered around the individual systems. An AF wide overview modeling activity could point to potential areas for saving costs and effort while increasing the effectiveness of the sustainment activities.

11. Space Sustainment Commonality Assessment

A high percentage of our Space Sustainment Study contacts indicated a major problem was a plethora of launch site test and support equipment that does essentially the same job. This complicates inventory, training and logistics support. Each space program and each launch pad seems to have its own aerospace ground support equipment. There would appear to be some cost savings to the Air Force if programs and launch pads would combine their thinking and agree to a standard set of equipment common to launch processing operations.

12. Modeling and Simulation for EELV Integration, Test and Launch

A common concern by personnel at the launch site and at AFSPC was t that there has not been sufficient logistics support planning effort on the government activities that will be required for the sustainment of the EELV either at VAFB or CCAFS. Since this is a contractor-provided service there needs to be coordination with government host organizations and potential payload users as to sustainment provisions

13. Post Launch Damage Assessment

During the operation of a launch vehicle the pad and surrounding facility areas are subject to extremely destructive forces. The explosive energy involved and in some cases corrosive nature of the propellants and other effluents cause substantial damage that must be repaired before the next launch is possible. Many pre-launch activities also take place on the pad so the timeline to refurbish can be critical to the Air Force's readiness to support space activities. Inter-launch refurbishment activities could be optimized if the actual condition of the launch emplacement is measured and assessed so that only the work necessary for turnaround is performed.

14. Logistics Decision Support Tool (LDST)

AF Space Systems program offices cannot adequately justify and defend logistics support decisions made during the acquisition process to show that the decisions made during this process provide for the delivery of a supportable, sustainable system, which achieves the performance, cost, and schedule goals of the program. An LDST research project will focus on applying technologies and developing a prototype tool / system that can effectively support the collaborative development, documentation, and evaluation of alternative system support concepts.

15. Maintenance Data Collection System Enhancements

Across all the space systems (Spacecraft, Launch and Ground) there are many methods for collecting maintenance and logistics data during operations. The effectiveness of these collection methods varies and most are not compatible with the overall USAF MDS. The nature of space systems as far as their employment and configuration stability from mission to mission requires that a fresh approach be explored to MDS. This is an extensive effort that includes not only gathering and compiling maintenance data, but also data mining and interface requirements to the AMC supply and support systems.

5.1 CONCEPT EVALUATION FACTORS

The overall goal of this effort is to identify research concepts that are appropriate for 6.3-funded development, which is Advanced Technology Development. To focus the effort on concepts for 6.3-type of development we used the following definition: "transition emerging technologies to system applications, as the basis for their incorporation into the defense system acquisition process"... Ref. Page 3-1, STG, DoD, April 2000.

AFRL/HESS has developed a method to evaluate project candidates as shown in Figure 6. These factors align well with the original selection criterion and provide a means to quantitatively rank the proposed topics.

Factor	Weight
Payoff/benefit to the AF	5
Customer Requirement	5
Mission Fit	5
Transition Potential	4
Technical Innovation	4
Risk	3
Safety	2
Jointness	2

Figure 6: AFRL/HES R&D Program Evaluation Factors

The highest weight factors are Payoff to the Air force, Customer Requirement and Mission Fit. In the sustainment area we drew these requirements from the deficiencies that were offered to us by the acquisition, operations and research and development communities we met with during the course of this study identified in our contact plan (See Appendix A). Payoff to the Air Force, high returns for investment in the development, increases in system availability and decrease in support cost are examples of this factor. For Customer Requirement we depended on the information gathered during our extensive interviews with operating personnel. For AFRL/HESS Mission Fit previous work by that organization was initially used to evaluate if the suggested task was in their purview or area of interest. Subsequently, direct input from AFRL/HESS was needed to assure that the concepts were in the area that the organization wanted to go in the future.

For the Transition Potential and Technical Innovation factor, sustainment equipment should be at the same level of state-of-the-art with respect to technology in order to support the operational equipment most effectively. For these factors, the state of the art was analyzed for the various concepts to see if there were new or emerging technologies that were appropriate for AFRL/HESS to develop and apply to these concepts.

Risk, Safety and Jointness are other factors that usually did not start or stop consideration of a concept but simply helped determine the criticality and/or cost of the development effort. The type of Risk being evaluated is Development Risk rather than operational risk associated with the equipment, system or personnel. Safety being evaluated is operational safety with respect to payloads, equipment and personnel. Jointness is an important consideration because space related technologies that improve mission assurance or reduce cost are so valuable that they are usually applied across all government space projects. With the trend to use contractor provided

services on space programs the jointness can include the commercial space sector through government to industry technology transfer programs.

5.2 SELECTED CONCEPTS AND DESCRIPTIONS

The 15 preliminary concepts that were developed from the initial discovery and analysis were then screened with the above criteria, to develop the concepts shown in this section. The team then ranked the 15 research concepts by applying the weighting factor. This weighting factor is shown on the bottom of Table 3. To gain further insight we reviewed the concepts at Project Reviews and with AFRL personnel whenever possible. This resulted in the preparation of Table 3 illustrating the relative rankings of all 15 concepts documented by this study.

5.3 RANKED RESEARCH CONCEPT DESCRIPTIONS

Detailed descriptions of the research concepts summarized in the previous section were developed and are included in Appendix A-5 in descending order of priority as shown in Table 3.

Table 3: Ranked Research Concepts

CONCEPT	AF Payoff	Customer Reqmt	AFRL/HES Mission Fit	Trans. Potential	Technical Innovation	Risk	Technical Safety	Jointness	Total	Rank
Mobile Facility ECU Core Module	16.43	17.86	7.86	9.71	11.43	11.14	5.14	6.00	85.57	8
SBIRS Crew Trainer	13.57	12.14	13.57	12.00	12.00	9.43	5.71	4.29	82.71	11
Propellant Loading Equipment	15.71	17.14	13.57	10.29	9.71	9.00	6.86	4.57	86.86	6
Remote Surface Inspector	12.14	13.57	12.14	9.14	13.14	7.71	4.86	4.29	77.00	15
Launch Readiness Assessment Tool	13.57	14.29	15.00	10.86	14.86	10.29	6.00	5.71	90.57	4
Optics Decontamination	13.57	14.29	11.43	9.14	14.29	8.57	6.57	4.57	82.43	12
Leak & Hot Spot Detector	14.29	12.14	10.71	8.00	13.71	7.71	6.86	4.29	77.71	14
On-Board Data Recorder/Telemetry Package	17.14	12.14	10.71	9.71	13.14	10.29	6.29	5.14	84.57	9
Microsat Launch Processing	18.57	13.57	14.29	12.57	14.29	11.57	6.29	5.71	96.86	3
Constellation Logistics Architecture	15.00	12.86	13.57	11.43	13.14	10.29	5.14	5.71	87.14	5
Commonality Assessment	15.00	15.71	12.14	12.00	9.14	11.57	5.14	5.43	86.14	7
EELV Model & Simulator, Integration/Test	15.00	13.57	10.00	9.14	9.71	10.29	5.14	5.71	78.57	13
Launch Pad Damage Assessment	18.57	13.57	12.86	10.86	8.57	9.43	5.71	4.57	84.14	10
Logistics Decision Support Tool	20.71	24.29	20.71	17.71	13.14	12.43	4.86	7.71	121.57	1
Maintenance Data Collection Enhancements	22.86	21.43	18.57	14.29	11.43	12.00	5.71	5.71	112.00	2
AFL/HESS Weighting Factors included in Calculations	5	5	5	4	4	3	2	2		

5.4 RESEARCH CONCEPT/ TECHNOLOGIES MATRIX

The technologies associated with the 15 research concepts are summarized in Table 4. Also shown in this figure are the sources of the deficiencies that lead to each research concept.

Table 4: Research Concept/Technologies

RESEARCH CONCEPT	SOURCE	TECHNOLOGIES INVOLVED
1. Mobile Facility Mdule	Derived from Det. 11, Det 9, SBIRS-LOW, DMSP	Environmental control, AGE, data management, sensors/control, human factors, mechanical/electronics
2. SBIRS-LOW Crew Module	SBIRS-LOW SPO	Simulation, data management, modeling, information processing, human factors, computer graphics, intelligent tutoring devices
3. Propellant Loading Equipment	Det 9	Environmental control, mobile/high precision, AGE, fluid flow mechanics, cryogenic handling, propellant tank age, fluid measurement, instrumentation, fluid couplings and contamination control
4. Remote Surface Inspection	Det 9	Tele-operations, automated scanning, machine vision, surface distortion, sensors/control, electronics, modular optics, recording systems, displays
5. Launch Readiness Assessment Tool	GPS, SBIRS-LOW SPOs & Det 9	Robotics, diagnostic/status instrumentation and related avionics, non-intrusive inspection, telemetry, displays
6. Optics Decontamination	STG, AFSPC, Det 9	Optics cleaning mechanical, electrical and chemistry technologies, decontamination measuring systems, telerobotics, displays
7. Leak and Hot Spot Detector	Det 9, STG	Robotics, sensors, fluid identification methods, thermal measurement devices, recording/displays
8. On-Board Data Recorder/Telemetry Package	Derived from SMC, AFSPC, Det 9	Telemetry, sensors, recorders on-board launch vehicles and payload data recorder with information transmitted to ground terminals
9. Microsat Launch Processing	STG	Multi-functional structures, advanced multi-chip modules, thin-film photovoltaic solar arrays, solid state batteries, multiple satellites per launch vehicle, rapid launch processing
10. Logistics infrastructure to support constellations	Derived SMC-XR Det 11	Modeling, simulation, data base management, tracking anomalies, secure communications, information networking
11. Commonality Assessment	Det 9	Inventory and configuration management, survey of AGE by program and launch site, network logic, derivation of standards, distribution of schedules
12. EELV Model and Simulator, Integration/Test	Det 9	Modeling, simulation, launch vehicle/payload integration, data generation, human factors, computer graphics, virtual reality techniques
13. Launch Pad Damage Assessment	Det 9	Facilities, AGE, information processing, robotics, sensors/detectors, recorders, structural damage evaluation
14. Logistic Decision Support Tool	SMC/AXL, AFSPC	Modeling, simulation, information management, artificial intelligence, expert systems
15. Space Systems Maintenance Data Collection System	AFSPC, SMC/AXL, Det 11	Information collection, manipulation and management, computer graphics, human factors

5.5 RETURN ON INVESTMENT (ROI) OF PROPOSED CONCEPTS

The primary focus and effort of the Space Systems Sustainment Front-End Analysis task was centered on gaining a better understanding of deficiencies, support requirements, and applicable tools and technologies that could contribute to improved sustainment techniques for space systems. The study team estimated and quantified (rough order of magnitude) the time and cost of developing and sustaining each concept. This was accomplished by applying best engineering estimates of the contractor team, and relating that to other quantitative benefits the Air Force might expect to realize. Some improvements suggested by the proposed concepts could result in: reduced training time – learning curve effects; reduced workload like time and resources - for logistics agencies that are directly involved in the process of developing support concepts and implementing logistics support of space systems. In addition to a quantitative analysis, some of the potential qualitative benefits we believe these concepts will contribute to the support process are also being included as part of an ROI analysis for each concept.

Typical quantitative and qualitative benefits of each concept evaluated include:

- Improving the process for developing logistics support concepts early on and throughout a program by providing a structured approach for decisions and supports the documentation of decisions
- Help novice logistics managers stay focused on the key decision factors and questions they need to answer as part of the process of developing a support concept, thereby reducing user workload requirements
- Help ensure that decisions are made in a more a consistent manner
- Retain the organization's expertise in a readily maintainable form ("experts" should be able to maintain rules in the knowledge base as logistics policies and procedures. Addressing the need to capture, and build-on critical corporate knowledge from logistics "experts" who will be leaving the workforce in the near future. A key DoD and private sector concern
- Reduce the labor involved with collecting and maintaining maintenance activity data
- Help to minimize the sustainment effort for launch vehicles and spacecraft
- Enhance ability to accurately assess the condition of operating equipment through the use of automation like expert systems
- Reduce training requirements and subsequently costs for operating and maintaining personnel. Explore the application of advanced instructional techniques to space systems
- Increase the effectiveness of maintenance and support
- Suggesting areas where consolidation of similarly functioning units can reduce the breadth of logistics inventory on common items. Then looking at and testing new technology applications for replacement line replaceable units
- Improve insight into the actual performance and availability of space systems in support of performance based contracted services

- Develop concepts for sustainment architectures that take advantage of advanced or emerging technologies, to reduce the cost of deploying, operating and supporting space systems

AFFORDABILITY PROCESS USED FOR THIS STUDY

The study team has followed the intent and concept of the Integrated Product Process Development (IPPD) Process with regard to affordability, throughout the performance of this task. The process used is consistent with the classic systems engineering processes. The following paragraphs present a discussion of the team's approach to affordability, desirability and cost estimation.

DETERMINING REQUIREMENTS

In our research and analysis, it was evident that space logistics/sustainability technology needs have not been specifically defined or called out in using or sustaining command Mission Area Plans (MAPs) and Technical Planning Integrated Product Teams (TPIPTs). However, the team noted that the Space Technology Guide (STG) is the most comprehensively documented compendium of space logistics/ sustainment needs that exists at this time, within the Air Force.

During the team interviews and follow-on discussions with the space system acquisition and sustainment personnel, the dialogue successfully surfaced several sustainment issues and requirements that currently exist. However, it should be noted that the team "requirements" and "deficiencies" identified during the interviews was obtained by extracting relevant information through the use of "what if" conversations with space system developers, operators, and sustainers. For example, the team found that space operators and maintainers are not usually provided an opportunity to input classic deficiencies that exist in today's space sustainment world. These agencies (and their personnel) work within the current processes, utilizing existing equipment, and software, until they attain the required levels of readiness for space related systems. Since the space and launch elements of space systems have low populations and are often only a few steps removed from an R&D configuration, in many cases the hardware and software used are pretty close to the state-of-the-art in regard to level of technologies used in the design of new spacecraft. However, logistics support resources to sustain these space systems often lag the operational hardware in the degree of "state-of-the-art" technologies used in their design and operations.

The transition of space systems launch, operations and sustainment to contractor provided services has essentially blunted many user priorities and needs for updating logistics support technologies associated with space systems. The concern found by the study team was that since the existing support systems "won't be around too much longer" there would be insufficient return on any investment (ROI) made in improvements in sustainment. The concern expressed with this approach is that there haven't been sufficiently strong sustainment provisions stipulated in the Operations and

Maintenance (O&M) contracts for commercial services. Consequently, there are no current, successful models available for sustainment of current systems for contractors to emulate.

EXIT CRITERIA

The exit criteria for affordability assessment of potential candidate technology sustainment items fits the six-step process described in the IPPD. The steps of the IPPD model include: establishing thresholds and objectives; defining desirability functions; organizing constructed requirements; weight those requirements; organize the exit criteria; and configuring the "scorecard". The team's approach for establishing tailored exit criteria for space systems technology needs are presented below.

THRESHOLDS AND OBJECTIVES IDENTIFIED FOR EACH ITEM INCLUDE:

1. The identified technology has potential for near term application
2. The development effort can be started in the next fiscal year
3. Estimated development cost is less than $5 million

DESIRABILITY FUNCTIONS:

1. A using USAF organization has identified the need or deficiency
2. The development item may have the capability for application to several generations of equipment
3. The development item will provide clearly defined sustainment enhancement, enablement and/or economic benefits

SCIENCE & TECHNOLOGY "PRODUCT" REQUIREMENT (CONSTRUCTED REQUIREMENTS):

1. Construct or derive the technology development item that fits AFRL/HESS mission and capabilities
2. Assist users in linking their sustainment needs with technology developments that will improve the overall effectiveness and sustainment of their space systems

WEIGHT RANK REQUIREMENT

Rank candidate items based on:

- Need
- Urgency
- Cost-to-develop
- Relevance to AFRL focused activity
- Estimated timeline to develop and deliver the improved/new capability to practice.

ORGANIZE SCIENCE AND TECHNOLOGY REQUIREMENTS

The bd team assisted AFRL/HESS prioritize the constructed requirements by providing technical support in the form of data and analysis performed in arriving at recommendations for the identified technology development concepts.

CONFIGURE THE SCORECARD

AFRL/HESS used the data provided by the team to begin populating the IPPD scorecard. Subsequently the constructed requirements were prioritized; exit criteria established; evaluated against the lab responsibilities; and documented the rational for each technology item recommended by the team. The result of this scoring is shown in the ranking of the concepts shown in Section 6.3.

DEVELOP TECHNOLOGY ALTERNATIVES

Deficiencies and requirements identified and screened in this effort have been evaluated and scrutinized as to the type of technologies that could be applied to develop solutions. The study team focused on candidate technology development items that showed potential relationship to technology development projects under way or recently performed by AFRL/HESS. This approach was selected as a starting point to determine if opportunities exist to leverage past/on-going technology development for near-term application to meet space sustainment requirements.

DEVELOP AND DEMONSTRATE TECHNOLOGIES

The study team has formulated draft, summary level development and demonstration plans for each candidate technology item identified by this effort based upon the level of data and information available. This information can form the basis of the Technology Transition with Business Case information called for by the IPPD process. In the review of the IPPD web site material, it appears that there is substantial supplemental information required to complete this process (i.e. need for estimated AFRL budgetary data and other Air Force development resources) that was well beyond the scope of this study.

ANALYZE AND DELIVER RESULTS

The final decision regarding continuing actions to fund and develop any of the candidate technologies rests with AFRL/HESS. Several of the concepts suggested in this study are derived from requirements and/or reflect deficiencies identified to the team during the course of this study. It is essential that the potential applications of such technology is fully supported by the using command(s) and that there is a fully funded transition agent that can carry on the development.

5.5.1 Key Logistics Considerations

The key considerations of any space logistics technology development program that directly and indirectly impact potential ROI include the items discussed below. At this time, all space systems sustainment is performed on the ground, with limited maintenance achievable via ground commands to the spacecraft to correct anomalies. In the future, however, space systems sustainment will include not only those functions that will continue to be performed on earth, but also will include selected functions that can and will be performed in-situ (in space). The considerations presented below include an amalgamation of sustainment operations that include both current and future operations. Therefore, the reader is reminded the considerations presented below will change over time, with program maturity, and the evolution of space systems and their supporting infrastructure:

- Cost of bringing the technology through transition to operational application
- Location where the logistics function will be performed, that is at the (1) government or contractor's assembly, integration, and test facility (2) launch site, or (3) mission control station
- Who will perform the logistics function – organic or contract personnel or a combination of both
- Commonality of hardware or processes to multiple customer organizations
- Impact on in-use standards, protocols and wing policies
- Potential for growth to include space-based and on-orbit logistics operations

Examples of key considerations under each element are as follows:

Cost

- Space logistics systems must be cost effective and program enabling
- Logistics pricing policy must be established for users in advance of spacecraft design and mission operations
- A national investment in the logistics infrastructure is required prior to achieving space program life cycle costs savings

Logistics location

- Where and who will perform the logistics functions; organic or contract personnel or a combination of both? Impact of new logistics standards, protocols, and training on wing policies.
- Near term strategy for on-orbit servicing will address logistics and maintenance sustainment of space assets in low earth orbits
- The evolution of the logistics strategy to polar, high inclination, or geostationary orbits will be a function of the cost benefits associated with the maintenance of assets in these orbits.
- Users of serviceable space assets must locate these assets in orbits compatible with an operational logistics system

- The maintenance or servicing of satellites at the International Space Station will occur when a logistics and servicing capability is available at the ISS and when such sustainment maintenance is warranted as paced by user requirements and economics

Servicing Functions
- Logistics and servicing of satellite systems is any activity performed on the ground (current) or on-orbit (future) to assemble, maintain, repair, replenish, upgrade, deploy, retrieve, or return various space systems, satellites or their support facilities
- How, when, and if each logistics function is performed on a space system in space will depend on the following: Technology status of the function; maintenance hardware availability to accomplish the work; operational need for quick response; number and location of the spacecraft to be maintained; and cost of the servicing mission versus spacecraft replacement cost

Common Hardware
- Baselining and development of generic maintenance equipment hardware and tools for various classes of spacecraft will preclude each program office from having to procure its own set of hardware and establish a program specific maintenance data base (e.g. "stovepipe" sustainment)
- A designated government organization (the Air Force or NASA) could own and issue (loan) the generic maintenance hardware to potential users and project offices

Transportation
- The (future) operational satellite logistics and servicing system must be compatible with expendable launch vehicles, the Space Shuttle, the SMV, and the OTV which are vital parts of any national logistics infrastructure for on-orbit servicing (and potentially, maintenance)

Standards
- Maintenance interfaces must meet recognized and agreed to interface standards
- Work should be accelerated to determine and define the requirements for robotic hardware/software and standard maintenance interfaces for satellite servicing

Operations
- Safety of the crew and equipment is paramount in mission planning, time-lining of events, and selection of infrastructure elements to accomplish on the ground and on-orbit logistics objectives for all programs
- Strong emphasis should be placed to identify compatible issues in the design of satellites and robotic maintenance systems, which promote a

cooperative environment for blended human factors and automated servicing operations

Technology

- A satellite maintenance logistics system flight demonstration program, sponsored by a government agency (USAF, DARPA, or NASA) will provide the confidence required to commit to a national operational set of logistics functions for on-orbit servicing and maintenance.
- There is a need to quickly mature the six critical technologies, described above associated with space maintenance
- There is also a need to utilize ground testing and simulation facilities for developing a remote logistics capability, first for ground-based operations, and then for on-orbit missions
- Specific and directed logistics research must focus on: (1) high (early) technology payoffs; (2) Determine if the payoff is specific to users or generic; (3) Define the sequence of technologies that affect the solution via flight demonstrations; (4) Determine how much innovation is needed

Growth Capability

- Satellite servicing infrastructure, and the related hardware/tools inventory, can evolve over time with mission needs
- All elements of the logistics infrastructure of the future must have built into it's respective program a growth or extended capability. These separate growth plans should be integrated and factored into the national space logistics program so they will be ready when the future Air Force programs come on line in the next five to ten years

5.6 RECOMMENDATION FOR SPACE LOGISTICS RESEARCH PROGRAM

The study team suggests a structuring of the 15 ranked Research Concepts presented previously into the three time-phased categories that follow. This restructuring would provide the basis for generating a recommended AFRL/HESS near-term space logistics research program. The categories are:

1. Product of the research concept can be transitioned to an operational system or process in one year
2. Product of the research concept can be transitioned to an operational system or process in two years
3. Product of the research concept can be transitioned to an operational system or process in three years

Table 5 presents the ranked concepts together with the research time period of performance and estimated cost for that period. At the end of the proof of concept, the product of the research should be ready for implementation into operational programs.

Should AFRL/HESS decide to initiate research activity on the four top ranked research concepts starting in calendar year 2002, an example program is presented below for consideration in Table 5.

- The four research concepts (LDST, MDC, Microsat Processing, and LRAT) could conceivably start at approximately the same time
- Microsat processing is a one-year effort
- Launch Readiness Assessment Tool is a one-year effort
- Maintenance Data Collection Enhancement is a two-year effort
- LDST is a three-year effort

Table 5: R & D time and cost estimate for the ranked Research Concept

RANKED CONCEPT	ESTIMATED R&D TIME PERIOD	ESTIMATED COST OF R&D
1. Logistics Decision Support Tool	36 months	$500 K
2. Maintenance Data Collection Enhancements	24 months	$1.0 – 20.0 M
3. Microsat Launch Site Processing	12 months	$350 K
4. Launch Readiness Assessment Tool	12 months	$300 - 500 K
5.Constellation Logistics Architecture	12 months	$150 K
6. Propellant Loading Equipment	8 months	$100 K
7. Commonality Assessment	12 months	$250 - 400 K
8. Mobile Facility ECU Core Module	24 months	$ 1.25 M
9. On Board Data Recorder	18 months	$1.0 M
10. Launch Pad Damage Assessment	12 months	$300 K
11. SBIRS Crew Trainer	18 months	$750 K
12. Optics Decontamination	24 months	$1.5 M
13. EELV Model and Simulator/Integrator/Test	12 months	$300 K
14. Leak and Hot Spot Detector	12 months	$500 K
15. Remote Surface Inspector	24 months	$2.0 M

As shown on Figure 7, when one research concept is finished, another is selected to start. In this manner, AFRL/HESS would have a continuous flow of advanced technology concepts to support the needs of space logistics systems users and operators. At any given point in time, three to four logistics research concepts would be in the product/process development stream. Figure 7 shows this time relationship for the four selected research concepts.

It is recommended that AFRL/HESS plan and program to perform at least one space research concept on space sustainment hardware on a continuing basis for transition to the prototype or test article form.

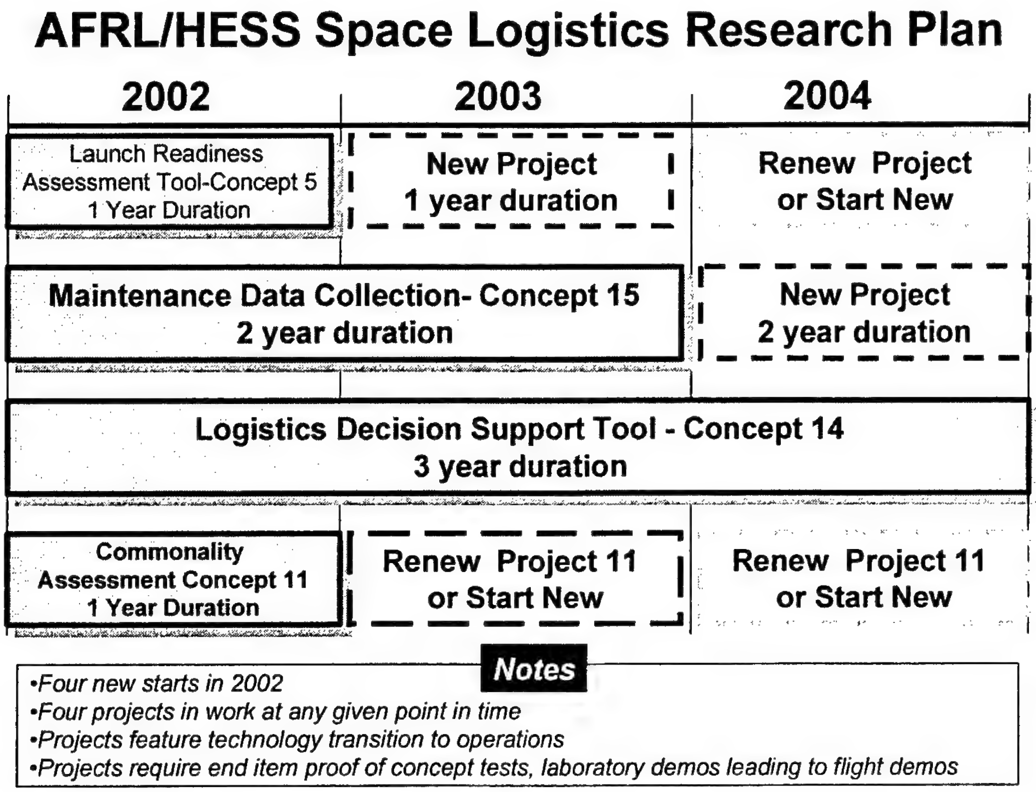

Figure 7: AFRL/HESS Space Logistics Research Plan

With three or four space logistics concepts undergoing research activity, there should also be a number of related technologies developed to enable the research concept goals. The technologies progress may then be programmed in a "spiral development" or "spiral acquisition" manner, thus bringing emerging technologies on line more efficiently in multi-year acquisitions or as hardware/software mature.

6.0 CONCLUSIONS

A fifteen-month Space Sustainment Front End Analysis study was performed for the Air Force Research Laboratory, Human Effectiveness Directorate, Wright-Patterson Air Force Base, Ohio from 20 April 2000 through 31 July 2001 by the contractor team of Litton TASC/bd Systems.

This report presents the findings and analysis performed under the Review of Current Space System Logistics. The findings and results are summarized below:

1. A plan was constructed to contact and interview Air Force Material Command and Air Force Space Command space logistics knowledgeable representatives, and included selected aerospace industry contacts familiar with the requirements for sustaining space systems. The purpose of this plan was to collect and document technical, management, and administrative logistics deficiencies as viewed by the interviewees.

2. Current Air Force and industry space logistics and sustainment practices and processes were reviewed, evaluated, and summarized in this report. The study team concluded that some current aircraft logistics practices are transferable to space systems sustainment, however new and innovative concepts, processes and equipment will be required to accomplish effective logistics and sustainment activities for future Air Force space programs.

3. During the course of the study, approximately 80 space logistics/sustainment deficiencies were identified and derived. All deficiencies were determined to be relevant to some aspect of space acquisition or sustainment deficiency that currently exists in the process of integration, testing, launch, operations, and life cycle sustainment of current Air Force space systems. A few of the deficiencies identified by the study team were considered serious, but none so critical that they would not benefit from infusion of new technology via research projects.

4. Technology assessments applicable to the deficiencies identified were performed and subsequently applied to the deficiencies to aid in the construct of a ranked list of fifteen (15) potential research concepts for AFRL/HESS consideration and implementation. These concepts and rankings include:

RANKING	CONCEPT
1.	Logistics Decision Support Tool
2.	Maintenance Data Collection Enhancements
3.	Microsat Launch Site Processing
4.	Constellation Logistics Architecture
5.	Launch Readiness Assessment Tool
6.	Propellant Loading Equipment

RANKING	**CONCEPT**
7.	Launch Pad Damage Assessment
8.	EELV Model and Simulator, Integration/Test
9.	Mobile Facility ECU Core Module
10.	On-board Data Recording/Telemetry Package
11.	Commonality Assessment
12.	SBIRS Crew Trainer
13.	Remote Surface Inspector
14.	Leak and Hot Spot Detector
15.	Optics Decontamination

The top four ranked concepts were further evaluated, and the analysis enhanced with an ROI. The findings were then structured into a near term, potential AFRL/HESS research program for space systems sustainment. (See Appendix A-5).

The U.S. Air Force is becoming a space force. Logistics systems must change to accommodate future DoD doctrine, missions, emerging technologies, and readiness requirements which supports the Space Commission's mandate that there be, *..."No Pearl Harbor in Space."*

With the rapidly emerging Air Force new space policies, it is very important that system acquisition and sustainment logistics requirements be developed and incorporated into future Air Force programs during the early stages of the programs' concept phase. An ongoing AFRL/HESS logistics research program will aid in giving perspective and credibility to developing these new requirements.

The conclusion is that the following top enabling technologies should be developed and applied to future space logistics concepts, and should be seriously considered for increased focus in AFRL for future study concepts:

- Data management, display and control
- Encrypted information processing
- Mobile, high precision aerospace ground and space based servicing, maintenance and repair equipment
- Robotic systems for remote, hazardous inspection, and replacement launch processing situations
- Human effectiveness to include user friendly logistics decision support tools (LDSTs) and protocols, human-computer interfaces, virtual reality of technical data, area training courses and equipment, allocation of human resources, human centered automated test-bed for check-out of new procedures and intelligent tutoring
- Standardized interchangeable software, electrical, mechanical, thermal, and fluid interfaces. This would include autonomous rendezvous and docking systems, fluid

couplings, C^3 practices, data distribution codes and addresses, and training procedures.

REFERENCES

1. TASC LETTER I0-117, 13 October 2000, directing that Task 1 of the DO12 Study Plan be revised to reflect adjustments discussed with Mr. Jeff Wampler (AFRL/HESS), to respond to his stated intent of maintaining flexibility in the specific performance of the study's Statement of Work subtasks.

2. bd Systems Subcontract 2000-075-DO-12 to TASC Task 1 Modification and Update, 17 November 2000.

3. Acquisition Logistics Research for Space Systems, Jeff Wampler, 19 January 2000.

4. PRC Phase 2 study Logistic Requirements for Space, On-Orbit Servicing 1999-2000.

5. Lightening Bolt 99-7, May 2000.

6. 4 May 2000, Draft DoD Space Technology Guide (STG).

7. Space Logistics Study, In Progress Review #1. 12 December 2000, at SMC.

8. Study Kick-Off Meeting at AFRL WPAFB May 2000.

9. Air Force Instruction (AFI) 21-108.

10. Space Commission Report, January 11, 2001, "Assess U.S. National Security Space Management and Organization".

11. The USSPACECOM Space Logistics Master Plan.

12. MIL-HDBK-502, Acquisition Logistics.

13. MIL-PRF-49506, Logistics Management Information (LMI).

14. SMC Critical Process Assessment Tools (CPATs).

APPENDICES

APPENDIX A-1
SMC Interview Points of Contact

SMC INTERVIEW POCs

Program/Name/Phone	Date/Time
DMSP/SESS; Caney Arnold, 310-336-4079	22 Sep/1:30
SBIRS/DSP; George Lemon, 310-363-6962	5 Oct/10:30
Space Lift Range/Network; Tony Lara, 310-363-3831	
GPS; Robin Pozniakoff, 310-363-6316	5 Sep
MILSATCOM; Jim Kerr, 310-336-4839	
Col (s) Lou Johnson, 336-4372	
Maj White, 336-4894	
Ian Martin, 336-4196	
Launch; Tony Pausz, 310-363-1860	22 Sep/10:30
Developmental Planning (XR); Maj Mark Hicks, 310-363-2341	3 Aug 00
VAFB Launch Vehicles (CL); Carolyn Pflepson, (805) 606-5023	12 Oct 00/0800
John Fitzpatrick, bd, (805) 606-7238	12 Oct 00/1000
Jim Ford, bd, (805) 605-2078	12 Oct 00
Lt Col Rob Hunt, Director of Logistics	12 Oct 00
CCAS Launch Vehicles (CL); Dana Jimenez (bd Systems) (407) 853-5633	
Satellite Control Network; L/C Ross Gobel SMC/CWSL (310) 363-5486	

APPENDIX A-1A
Space Sustainment Study Roster

SPACE SUSTAINMENT STUDY

Name	Org/Project	Phone	E-Mail
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Name	Org/Project	Phone	E-Mail
	(ARINC)		
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bd® SYSTEMS

APPENDIX A-2
Space Sustainment Study
Contact Interview Questions

SPACE SUSTAINMENT STUDY
CONTACT INTERVIEW QUESTIONS

The following questions used during SMC and AFSPC contact interviews and data collection is intended to catalog the information gathered for ease of analysis, and to facilitate the data gathering surveys. The data gathered have two purposes: 1) from stated or derived logistics deficiencies identified by the individual surveyed, the team will identify near and long term research project candidates that may be sponsored by the AFRL/HESS; and 2) the description of information used by the interviewees to formulate decisions (i.e. sustainment and key features of a decision support tool with utility for the interviewee in performing his/her responsibilities), will be used to form the basis for developing one or more logistics decision support tools.

NAME: ______________________________

ORGANIZATION: ______________________

PHONE NUMBER: _____________________

E-MAIL: _____________________________

QUESTIONS

1.0 General

A. Program or function for which you provide support: ______________________

B. If an acquisition program, what is the current acquisition phase of the program: ______

C. If a sustainment function, how are requirements identified, flowed down, directed, or derived that you or your organization must implement? (i.e. PMD, ORD, CONOPS, or other program documentation) ______________________

2.0 Logistics Operations

A. Describe/summarize the logistics tasks that you, or your organization typically perform (please use the back of this form if additional space is needed: ______________________

____

B. Do you contribute to developing support or maintenance concepts/plans for new or modified systems/subsystems? Yes _____ No _____

Describe your process: ______________________

____

C. What typical type(s) of analysis must you perform to make/recommend support concept/planning decisions? (i.e. LCC alternatives; sustainment risks; schedule impacts; operational constraints/impacts; others?) ______________________

D. How frequently must you update this analysis? ____________________

How is this documented? ____________________

E. Are there any analysis tools that you use in developing these concepts/plans? Yes _____ No _____. Describe the tool(s) used and their application:

____

____

F. If no tools were available for your specific analysis/decision application, what type of tool(s) would be helpful? (See #5, Modeling and Simulation below)

____

____

G. Is there any recurring set of information/data that is used in performing the analysis? Yes _____ No _____. Is it readily retrievable for your use, and how? (i.e. electronically)

____

____

H. Do you use any Maintenance Data Collection (MDC) data in the analysis? Yes _____ No _____. If not, what data is available/used and is it readily accessible to you? ____________________

____

I. Do you have access to experts in specific disciplines (i.e. LCC or risk assessment) to assist in performing analysis and trades to validate a support concept/plan? Yes _____ No _____. Do you need such help? Yes _____ No _____.

J. Are there any other areas of your job that expert input would be helpful to have available? ____________________

____

K. Do you use existing military and/or AFSPC standards/instructions in performing your work? Yes _____ No _____. If so, what standards/instructions are used by your organization? ____________________

L. Are there any policies, directives, or constraints you must follow in establishing or enhancing a sustainment program for the system you are supporting? ____________________

____

____

Are they helpful/necessary? Yes _____ No _____.

Can these be waived? Yes _____ No _____. Comment: ____________________

____

M. How do changes in readiness levels affect your organization? For example, if operational readiness levels deteriorate, how must your office respond? ____________________

____

____

N. Are there any forward base support and/or mobility issues (overseas) involved in your area of responsibility? Yes _____ No _____. Describe: ____________________

What types of actions and/or decisions are necessary for you to respond?

O. Are you ever required to respond to CONUS based quick action tasks or drills involving the logistics support of the system you are working? Yes _____ No _____. How do you accomplish these tasks?

Are there any methods/processes that cause delays or problems in allowing you to respond to the task requirement in a timely manner? Yes _____ No _____ Describe:

P. Does your work involve the generation or verification of new or updated logistics support systems? Yes _____ No _____. Describe:

Q. Are there any new activities and/or responsibilities that your organization will be undertaking in the next few years that could require, or benefit from, specific logistics R & D effort? Yes _____ No _____. Describe

R. Can you identify any job issues, problems, and/or deficiencies that constrain or impair effective job performance? Describe:

3.0 Technology

A. Describe any areas of your job that might benefit from introduction of new or improved technologies?

B. What tests, checks, or investigations do you perform?

What tools or equipment is do you use in performing this task?

Are they adequate for the job to be performed? Yes _____ No _____. If no, why?

C. Do you conduct any complicated integration or assembly tasks that might benefit from enhanced technology application? Describe:________________________

D. What work planning and/or schedule aids do you use? Describe use and functionality:________________________

Are they adequate for the job to be performed? Yes _____ No _____. If no, why?

E. Can you identify any key <u>technology</u> problems (Hardware or software) or issues (i.e. processes) that prevent or impair your job performance? ________________

F. Can you identify any known deficiencies in technology or any technical logistics support requirements? Describe:________________________

4.0 Support Equipment and Facilities

A. What support equipment and test, diagnostic and measuring equipment (TDME) do you currently use? Describe:________________________

Are they working properly or efficiently? Yes _____ No _____. If no, describe: ____

B. Does your operation utilize a standard set of logistics support equipment at each of your operating locations? Yes _____ No _____. If no, explain why: ________________

C. Do you envision any new requirements/needs regarding equipment or facilities important to successful accomplishment of tasks? Yes_____ No______. If yes, explain:

D. Are there any special or unique calibration requirements needed in your work? Yes _____ No _____. Describe: ________________________

Is/will adequate equipment be available to meet this requirement? Yes _____ No _____. If no, explain why: ____
____

E. Are there any special skills required to operate your equipment? Yes _____ No _____. If yes, are they being met? Explain: ______________________________________
____
____

F. Are the required skills organically available in the government, or are they provided as part of a commercial manpower contract? Government_______ Contractor_____

G. What training programs do you have to maintain or operate the mission equipment? Describe:____
____
____

Is the training and/or training equipment adequate? Yes _____ No _____. If not, explain:____
____

H. Do you have any support equipment or facility problems/deficiencies that are constraining or hindering successful mission accomplishment? Describe:______
____
____

5.0 Modeling and Simulation

A. What prediction or evaluation models do you presently use? Describe: ________
____
____

B. Do you currently use any DoD logistics models or simulations (i.e. NRLA, COMPASS, CASA, LOGPARS, etc)? If so, please identify and describe their application to your needs. ____
____
____

C. Do the models or simulations meet your needs? Yes _____ No _____. If not, please describe the deficiency: ____
____
____

D. If you do not use DoD tools, do you use commercial and/or space-unique models or simulations in your decision-making? Describe: ______________________________
____
____

E. Do you use modeling for planning purposes? Yes _____ No _____. If yes, please describe the models and their application: _________________________________
____

F. Are the tools you use meeting your needs? Yes _____ No _____. If not, please describe the deficiency: ______________________________

G. Would you consider the use of Intelligent Software Agent (ISA) tool in your decision-making process? (ISA is a software agent that uses Artificial Intelligence (AI) in the pursuit of the goals of its user.) Yes _____ No _____. If not, why: ______________

H. Can you suggest any technical or processing requirements important in the development of new logistic support tools or are there any deficiencies you know of that will lead to the derivation of requirements? ______________________________

APPENDIX A-2A
Introductory Briefing for Interviewees

Space-Log FEA

Space Sustainment Front End Analysis

Air Force Research Laboratory
Human Effectiveness Directorate

For Project Information Contact:
Project Manager
Mr.. Jeff Wampler AFRL/HESS
Wright Patterson AFB, OH
(937) 255-7773

Space-Log FEA

Approach
Investigate Logistics Deficiencies

- Review Acquisition, Operational Unit, and Depot Logistics Functions
- Perform working level survey and assessments to identify and/or derive deficiencies. Definition of hard requirements is a bonus
- Map deficiencies against emerging technologies and AFRL/HESS program "criterion"
- Identify near and long term potential research projects
- Perform preliminary Return on Investment (ROI)
- Develop technology roadmaps for programs selected by AFRL/HESS

Space-Log FEA

Technology Enhancements for Improving Space Sustainment
- Areas Evaluated for Potential Improvements -

Launch
- Launch Vehicles
- Payload Processing
- Launch Operations
- Range Operations

Constellation Operations
- Ground based

Control
- Satellite / Sensor telemetry, tracking, command and control systems

User Equip & Terminals
- Joint service requirements
- O&M Procedures
- Training requirements
- SOR considerations

Resources for Logistics Support
- Ground and Flight Support Equipment
- Logistics Support Facilities
- Manpower & Personnel
- Training and Taining Resources
- Modeling and Simulation
- Maintenance Procedures and Plans
- Replenishment Spares and Repair Parts
- PHS&T Processes and Resources
- Technical Data
- Software/Firmware Supportability
- SOR/LOR considerations

Space-Log FEA

Interview Purpose

- One objective of the Space Sustainment Study objective is to identify and/or derive a number of deficiency data-driven potential research projects that AFRL may explore using Air Force 6.3 development funds
- The study team is now beyond the half-way point. Fifteen candidate logistics research projects have been identified to date and are now undergoing further review.
- Government and industry users and maintainers of space systems have, and are being interviewed to solicit additional candidates for AFRL study consideration.
- Selected candidates are included in this package to illustrate the type of information being solicited from the interviewees.

Space-Log FEA

Logistics Research Topics-Examples

Research Topic	Source	Technologies Involved
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

APPENDIX A-3
AFRL/HESS Transmittal Letter

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE OHIO 45433

MEMORANDUM FOR: SMC/DET11/CC (COL. RICH HAYES)

FROM: AFRL/HES
2698 G Street
WPAFB, OH 45433-7604

SUBJECT: Request for Support for Space Sustainment Study

1. The Air Force Research Laboratory, Deployment and Sustainment Division (AFRL/HES) at Wright Patterson Air Force Base, Ohio has awarded a study contract to Litton/TASC and bd Systems, Inc. to investigate space sustainment and logistics research requirements. The goals of the study are to (1) develop a prioritized list of Air Force space system sustainment deficiencies that can be solved through research projects by AFRL, and (2) generate the framework for a Logistics Decision Support Tool for space systems. The study effort will run from April 2000 through July 2001.

2. As you are aware, sustainability and reconstitution of space assets is key to the military potential of payloads, spacecraft, and platforms. In this study, logistics infrastructure and decision tool requirements and needs will be collected, in part, by a series of interviews with key logistics personnel in a variety of government, military (including SMC and AFSPC), and commercial space organizations. The results of these interviews, as well as the other findings from the study, will be documented in a final AFRL technical report to be published next year.

3. We are requesting your assistance in identifying key personnel within SMC and AFSPC, and arranging meetings with our AFRL and contractor analysts for the purpose of identifying and analyzing space logistics needs. My project manager, Mr. Jeff Wampler, along with his current SMC point of contact, Mr. John Cox (SMC/AXL), will be following up with you to arrange a meeting to discuss the study details and the road ahead. Your support is vital to this work, and I greatly appreciate your assistance.

4. Contractor team members include: Mr. Terry Jenkins, Mr. Don Waltz, Mr. Bob Dellacamera (bd Systems, Inc), Mr. Pat Vincent and Mr. Scott Lawrence (TASC, Inc). Our point of contact is Mr. Jeff Wampler, AFRL/HESS, DSN 785-7773. The Space and Missile Center point of contact is John Cox, SMC/AXL, DSN 833-5433.

// SIGNED //
JAY KIDNEY, Col, USAF, BSC
Chief, Deployment and Sustainment
Division

cc:
AFSPC/SCT (Col. John Collier)
AFSPC/LG (Col. Kai Norwood)

APPENDIX A-3A
Mail Ahead Briefing Charts

Slide 1

Litton
TASC - *TRS Team*

Space Sustainment Front End Analysis

Air Force Research Laboratory
Human Effectiveness Directorate

For Project Information Contact:
Project Manager
Mr.. Jeff Wampler AFRL/HESS
Wright Patterson AFB, OH
(937) 255-7773

Note: Explanatory text is included with the following information

Slide 2

Litton TASC *TRS Team* **General Information**

- **Delivery Order Title: Space Sustainment Front-End Analysis**
  - AFRL/HESS WPAFB
  - Contractor: Litton/TASC and bd Systems, Inc
  - POP: 20 Apr 2000 - through 20 Jul 2001 (15 months)
- **Objective: Identify future logistic research opportunities in AF space systems, and baseline the groundwork for an advanced logistics analysis capability for space systems**
- **Study Time Frame: Near Term 2000-2005**
- **Key People:**
  - Government: Jeff Wampler, Project Manager (937)255-7773
John Cox , SMC/AXL (310) 363-5433
  - bd Systems- Terry Jenkins, (310) 618-87988,
Bob Dellacamera, (949)830-8778,
Don Waltz, (949) 472-0500
  - Litton/ TASC- Pat Vincent, (937) 426-1040
Scott Lawrence, (937)426-1040 ext.. 288

The Air Force Research Laboratory Deployment and Sustainment Division (AFRL/HESS) at Wright-Patterson Air Force Base, Ohio has embarked on a multi-phased program to identify future research opportunities in Air Force systems to establish the groundwork for advanced logistics capabilities.

Purpose of this Document

The purpose of the following charts is to provide the reader with a “quick look” at the Litton/TASC – bd Systems, Inc. Space Sustainment Front End Analysis study prior to establishing personal contact (visit, phone, fax, email) by one or more members of the AFRL/HESS and contractor study team. Once authorized contact has been established, specific questions will be asked of the respondents depending on the background experience, organization, and role of the person being interviewed (See final chart in this package for an example).

Slide 3

Litton TASC — *TRS Team*

Space Sustainment

- This Study has Two Major Tasks -

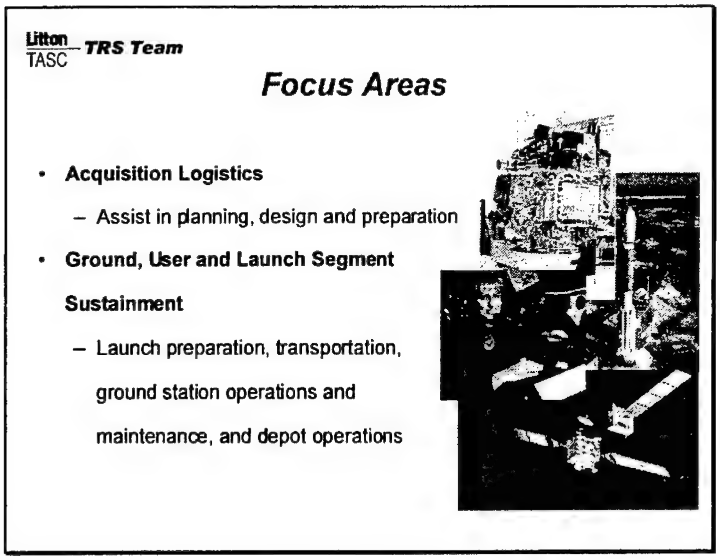
- TASK 1 - Re-look at logistics deficiencies
  - Acquisition, Operational and Depot Logistics
  - Working level assessment (requirements a bonus)
  - Map against emerging technologies and lab program "criterion"
  - Perform preliminary Return on Investment (ROI)
  - Develop technology roadmaps for selected programs
- TASK 2 - Develop requirements for an acquisition logistics decision support tool (SMC/AXL)
  - Source of repair and other sustainment analysis processes
  - Ground and user segments
  - Determine proper mix of organic and contractor logistic support

The current study consists of two tasks that are intended to help focus AFRL/HESS' technology development effort in support of space logistics activities over the next 10 years and beyond.

Task 1 is a further investigation of space logistics deficiencies that were not fully definitized in earlier studies. The chart illustrates the focus areas of this task.

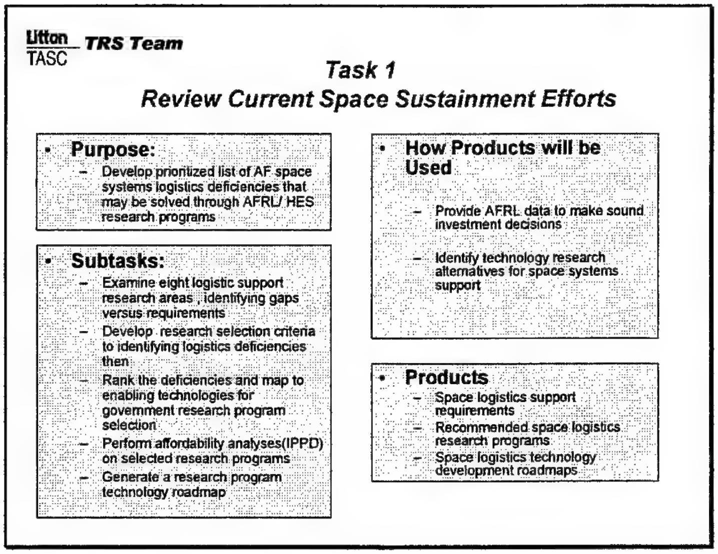
Task 2 is to develop functional and user requirements for a Logistics Decision Support Tool (LDST) that is intended to facilitate the evaluation of potential support concepts, or proposed changes to methods of sustainment under consideration for USAF Space systems, software and/or procedures.

Slide 4



It is the team's intent to be as inclusive as feasible in examining and identifying all aspects of space systems supportability to identify space logistics deficiencies. In a previous study AFRL determined that space logistics efforts practiced in the past focused almost entirely on the system acquisition phase due to the expendable nature of past and current military space systems. The primary focus of this study, however, will be upon examination of the sustainment needs and deficiencies of terrestrial systems associated with space systems.

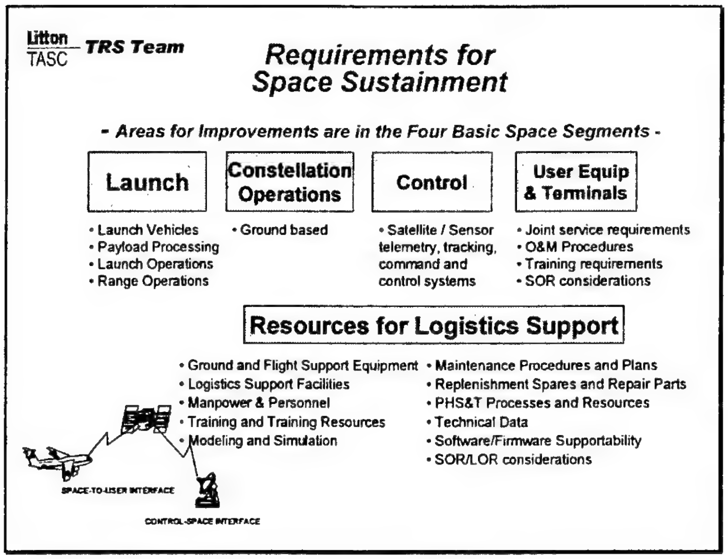
Slide 5



The team's approach for Task 1 is to review current Space Logistics effort as well as USAF Space Planning and Space Technology developments in each of the space segments. The emphasis during this effort is to focus upon ways for advanced technologies to improve support to the launch, control and user segments with a goal of increasing readiness, decreasing cost, and improving responsiveness to meet current, planned and anticipated future operational requirements.

The study approach will be patterned much like a "blue two" visit that elicits comments and observations from personnel most directly involved with the operations and sustainment processes and practices used by the using and sustaining commands. As the data is collected, it will be cataloged and results displayed in matrix form by logistics and element parameters as the study progresses. The resulting products will be used by AFRL/HESS to help plan the laboratory's future research investments. The study findings will also be shared with SMC SPO's and operational organizations to stimulate enablement for continued improvements in US military space capabilities.

Slide 6



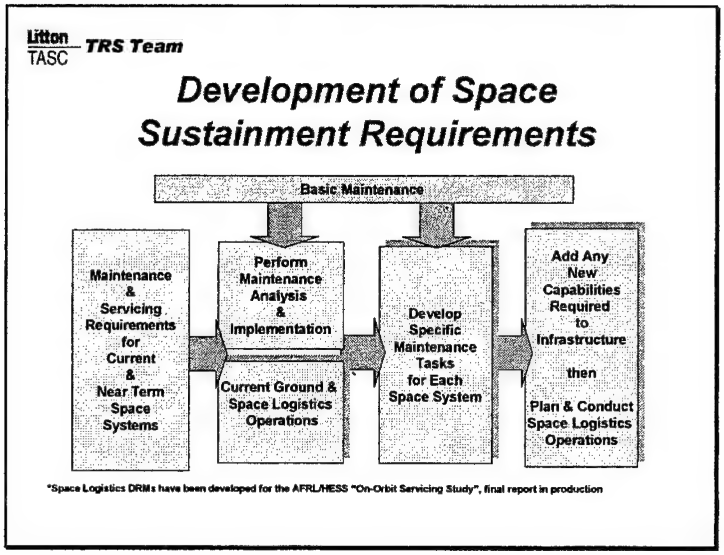
This chart depicts the four basic segments of space systems. In examining the breadth of equipment and operations involved one gains some insight into the problem of integrating unique space logistics needs and associated military space systems.

Each segment operates more or less independently and logistical support is broken out into a number of separate compartments unique to each individual program's needs (i.e. "Stovepipe"). The challenge for logistic planners and implementers is to ensure that the evolving military space systems have the support they need when they need it, throughout their life cycle. The chart shows the specific areas within each segment that the study will examine to identify deficiencies/constraints to logistics support that may currently exist, and possibly to define new requirements to enhance and improve logistics support for each segment. Each segment will be examined by program and collectively across programs in an effort to identify potential areas for commonality and consolidation of support efforts wherever possible.

The starting place for the study is to examine and identify deficiencies/requirements that may reside in the resources currently used to logistically support the space segments. In the past, the support systems developed for sustaining Space systems have historically been completely tailored for the specific program being sustained, resulting in what is often known as "Stovepipe" support. This method of supporting space systems has contributed to several documented inefficiencies and redundant capabilities.

The team will solicit specific examples of deficiencies and needs during the survey.

Slide 7

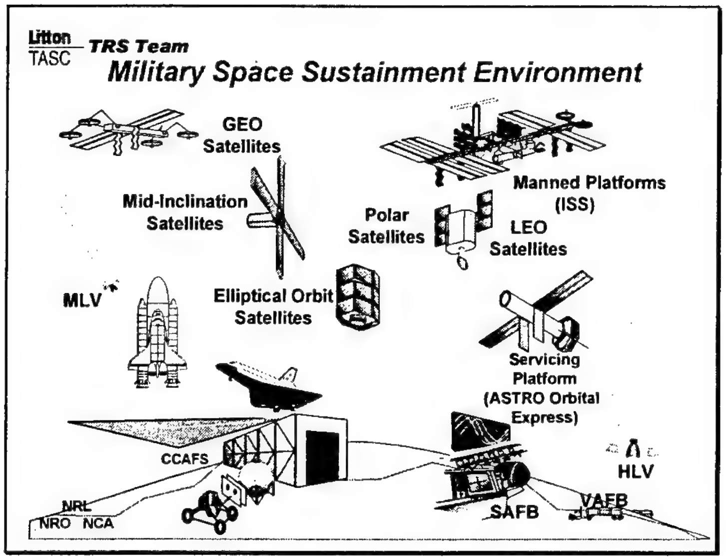


The method used by the study team for developing space logistics requirements follows the typical trade study process and techniques used for terrestrial systems.

The sequential process shown in this chart recognizes two unique aspects of military space programs that make them difficult to support: (1) The systems are small in numbers of like equipment hindering the ability to forecast and assign given that the data is not statistically significant; and (2) there is at this time an inability to physically access spacecraft for servicing once they are launched into orbit.

The goal here is to first understand the current sustainment processes, then to identify and or anticipate the varied logistics needs for each of the elements of space systems so that any new technology, process or administrative requirements can be accommodated in a timely manner. Requirements will be further categorized as near term, 2000 through 2005, and far term, 2006 through 2010.

Slide 8



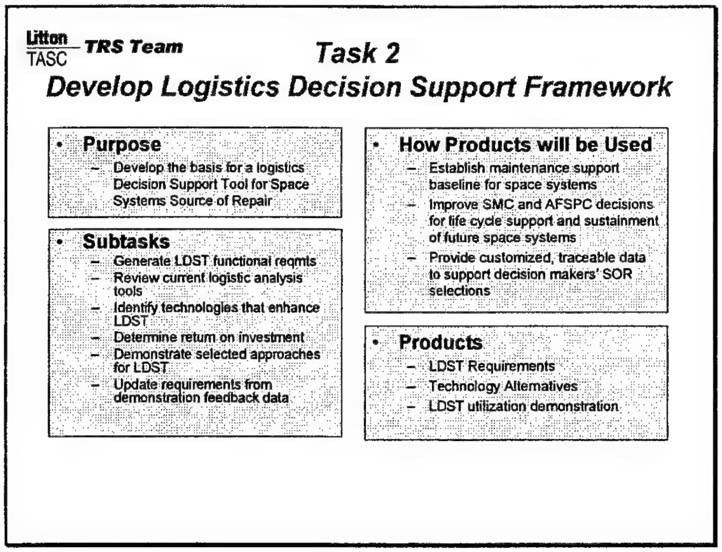
Military space hardware uses a range of technologies and implementations in many orbital and terrestrial locations. As illustrated in the chart, each space element locates its command and user operations at several different locations, and the resulting logistics organizational and intermediate support levels have evolved to sustain the peculiarities of each system.

The launch segments operate at Cape Canaveral AFS and VAFB with the logistics efforts focused upon preparing vehicles and payloads for launch into orbit. As reusable launch vehicles become operational, these facilities will also become the prime areas for recovery, repair and recycling operations. The space shuttle operations are accomplished primarily by contractors; the USAF is only involved in infrequent military payload preparation and recovery. Although not an unreasonable model to start from, the payload and transportation processes have not been optimized for military use. The model the AF is striving for is akin to the C-17 scenario: Load, fly, unload- - - prepare for the next launch!! In this way efficiencies and cost of space operations will tend to improve.

Air Force spacecraft operations and control is centered at Colorado Springs with adjunct facilities at various locations to assure redundancy and survivability. The equipment used for this function is mostly for communications, station keeping, payload management, and vehicle control purposes. Logistics support of the hardware and software is focused on maintaining the readiness of electronic equipment and software. The spacecraft itself is supported remotely, though up-linking commands and software changes.

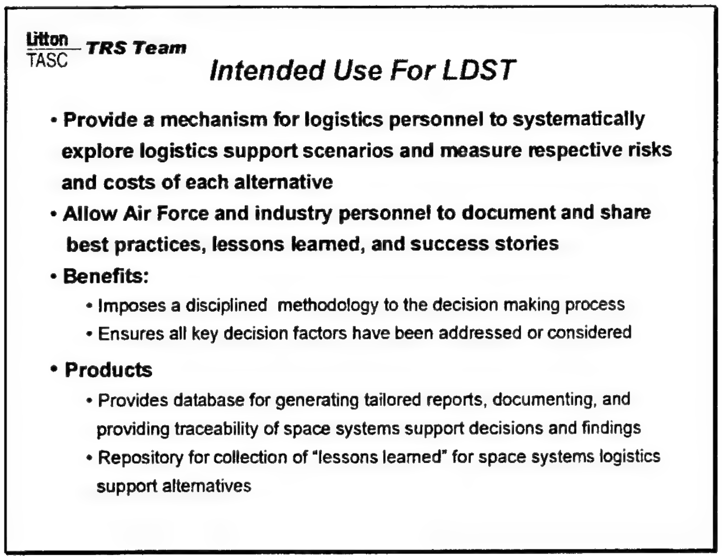
User segment logistics support is also principally electronic based coupled with the added requirements driven by the need for many user systems to be mobile or transportable. Some user systems include fairly high populations of in-use equipment and are supported by traditional three- or two-levels of logistics support echelons within their respective services.

Slide 9



Many models and computerized tools currently exist in the Air Force that address processes or specific elements of logistics as applied to terrestrial and air breathing systems, e.g. source of repair, level of repair, training technical data and alike. Some of these tools may have direct or indirect application to space systems. However, space systems are relatively few in numbers, are launched into orbit to perform their mission, and can rarely be accessed (with exception of low altitude satellites accessible by the shuttle) for servicing, replenishment or repairs during their lifetime. This unique aspect of sustaining space systems may demand a different approach to logistic decision making tools than traditional aircraft based tools. The primary focus of this task is to develop a set of requirements and a functional specification for developing a space logistics decision support tool that can be used by the acquisition, development, sustainment, and operational commands. This chart provides an overview of the approach and products that will be provided by the team in performing Task 2.

Slide 10



The Logistics Decision Support Tool (LDST) for space will provide the means to facilitate the analysis of sustainment alternatives balancing cost and mission considerations for launch/ recovery, space operations, spacecraft control and user support. The shortfalls evident in most traditional logistics tools are that they tend to be too ponderous for use on space projects since they usually are designed to evaluate complex logistics infrastructure systems that support geographically dispersed, highly populated military systems.

Since space systems can be extremely complex in order to perform multiple missions, the logistics approach often selected is tailored to meet each operating system's unique sustainment needs. This "stovepipe" approach limits potential cross-application or opportunities for common or standardized support processes, maintenance equipment, or tools. This is but one of several logistics support decision factors to be incorporated in the design of the LDST.

The intended use and utility of the tool is to impose a disciplined methodology to the decision making process; ensure that all key and applicable decision factors are addressed or considered; provide traceability of each decision, and it's supporting rationale; and provide a repository of "lessons learned" accumulated by both government and space industry in their sustainment of past and current space systems.

Slide 11

Litton TASC *TRS Team*

Expected Application Of LDST

Potential users: SMC SPO's, HQ AFMC, HQ AFSPC, HQ IL/AQ, and aerospace industry

- **SPO's Logistics Managers**
  - **Determine optimum support approach - detailed**
  - **Document the decision process & support "no" decisions**
  - **Useful in defending positions throughout the acquisition process (traceability)**
- **AFSPC**
  - **Assists in verification that requirements (mission critical) are met**
  - **Allows full participation in and input to the support concept development and maintenance planning process**
- **HQ AFMC/PEO/DAC and HQ IL/AQ**
  - **Insures consistent, logical approach was used to develop a recommended support approach**
  - **Provides retrievable rationale (with traceability) for recommendations**

Currently, there is no structured methodology in place for guiding the acquisition logistician to ensure that all programmatic, legislative, regulatory, and cost considerations are adequately addressed in arriving at, and recommending a defendable, specific logistics support plan for new and modified space systems as the programs evolve through each acquisition and development phase. This often results in a lack of consensus by the using and sustaining space community in arriving at an optimum support scenario.

By allowing active participation, and contributing input to the LDST during the design and development phases of a new space system, the LDST is expected to assist the using command verify (in part) that the mission critical and sustainment requirements described in the TRD, SOR, and CONOPS have been achieved.

Each major space program is typically reviewed at the SAF/AQ and intermediate levels prior to progressing to the next acquisition milestone. The LDST will provide a readily accessible means to give senior managers at each command echelon improved insight and understanding of the support alternatives and decisions made by the program office's acquisition logistics manager during each major design review.

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Litton TASC *TRS Team*

Space Sustainment Study

Potential Benefits

- **The products will provide a fresh and current look at USAF requirements for logistics support of space systems**
- **Potential logistics technology development areas will be identified for AFRL investment decisions**
- **A framework will be prepared for developing a Logistics Support Decision Tool for SMC, OOALC and AFSPC users**
- **A natural user work group will be re-established within the USAF acquisition, development, operator, sustainer, and user communities to address future space logistics issues and requirements**

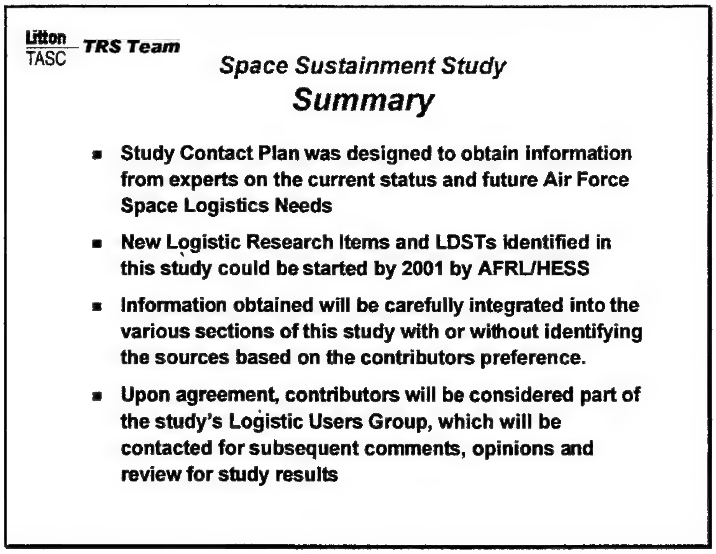
This study by AFRL/HESS is focused to ensure that candidate space logistics research items offering a high rate of return on investment are identified and potentially developed by AFRL/HESS in a timely manner to enhance and improve the sustainability of our space assets.

The team will examine logistic needs from the perspective of the operator, user, sustainer, and transportation elements during this study project. The study team will explore both long and short-term logistic requirements to help ensure USAF readiness in space, with focus upon those short-term requirements that could provide near-term improvements to sustaining our space systems.

Decision support tools and models that will provide assistance to analysts are needed to facilitate the many support and maintenance support decisions required during the development phases to ensure that the space system is supportable.

The establishment of a standing working group comprised, as a minimum, of SMC(AX), AFSPC(LG/SC), ALC(OOALC), and HQ AFMC representatives that can be rapidly re-convened to address space logistics needs and issues across the Launch, Space Ops, Spacecraft and User communities. The constituency for this group coming from the acquisition, development and user communities will ensue space logistics products and services are affordable, applicable and available to support operations when required. As the future of space logistics enfolds, such a constituency will be essential to ensure that the lessons learned and evolving technologies are properly applied to meet the future needs of the Air Force in space.

Slide 13



Space sustainment has been examined over the years to support various satellite programs. This study is intended to obtain current information from the experts currently operating and sustaining the space systems. The intended output is identification of potential research items for AFRL near-term investment, and a detailed set of requirements for a much needed Logistics Decision Support Tool for the space acquisition logistics community.

The study reports will provide reference to all source materials, including (with permission) individual subject matter experts interviewed during the data collection phase.

It is the study team's hope that the logistics working group relationships developed throughout the project period is maintained to assist the space sustainment community in the validation of future space logistics requirements and developments as they evolve.

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Litton TASC **TRS Team**

Study Team Information

- This is the Information We will be Looking For -

- **Task 1 Logistics Research Opportunities**
  - **Which AF Logistics doctrine and policies are important to this study**
  - **Can you provide inputs to the logistics parameters matrix**
  - **What is current status of logistics support activities in your area?**
    - How hard is it for you to achieve required readiness levels?
    - Is the current AF logistics system to support your activities effective?
    - Do you use "workarounds" to meet readiness levels?
  - **Do you have any Logistics issues, problems, requirements that relate to one or more Space Segment?** (See Logistics Requirements for Space Systems chart)
  - **What are your opinions or comments on needed logistics standards?** (i.e. Are current measures of efficiency and/or effectiveness adequate to define the true state of the fleet?)
  - **Do you have any thoughts on how can we shorten launch preparation times, reduce duplicative logistics tasks, and lower logistic costs?**
  - **Can you identify enabling technologies to help solve your logistics deficiencies?**
- **Task 2 Logistic Decision Support Tool**
  - **What logistic decision support tools are now used for space systems?**
    - What are their limitations or deficiencies? What are their attributes?
  - **Do you have any specific requirements for new logistic decision support tools?**
    - What are the important criteria for tool selection?
    - What techniques should be used for these tools?
  - **If a new LDST is developed from this study, what impact will that have on your training requirements?**

These general questions establish the areas of information the study team will examine in this study to define logistics needs and identify requirements for developing a LDST with utility for both the acquisition and using communities. The team realizes that each organization contacted during the surveys may emphasize one or more element based upon natural biases; however, it is important for all users and sustainers to present their view of the current deficiencies and requirements to capture the largest cross-section of input data possible for the study team.

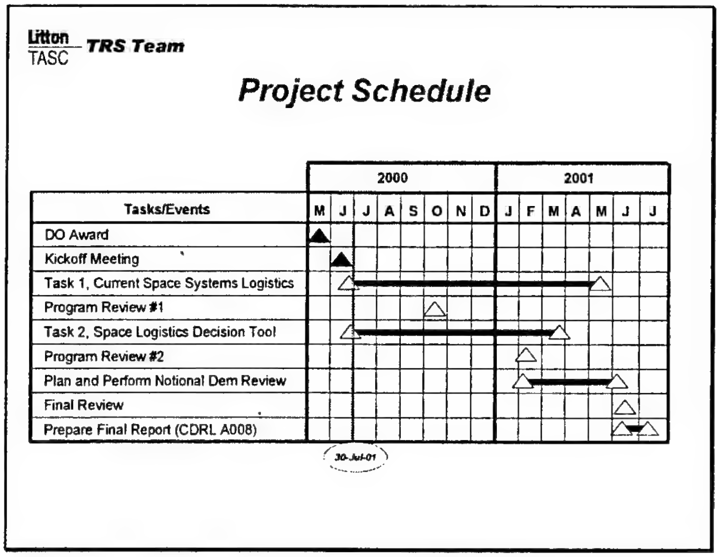
The intent is to identify and document problems, suggestions, techniques and the needs of a large cross-section of the Air Force space organizations and the people engaged in military space programs. It is expected that the formation of a logistics working group will underscore the importance of interrelationships, coordination, and cooperation necessary among the Air Force developing, using and sustaining organizations for successfully supporting and sustaining the space systems of the future.

Slide 15

Litton TASC TRS Team

BACKUP INFORMATION

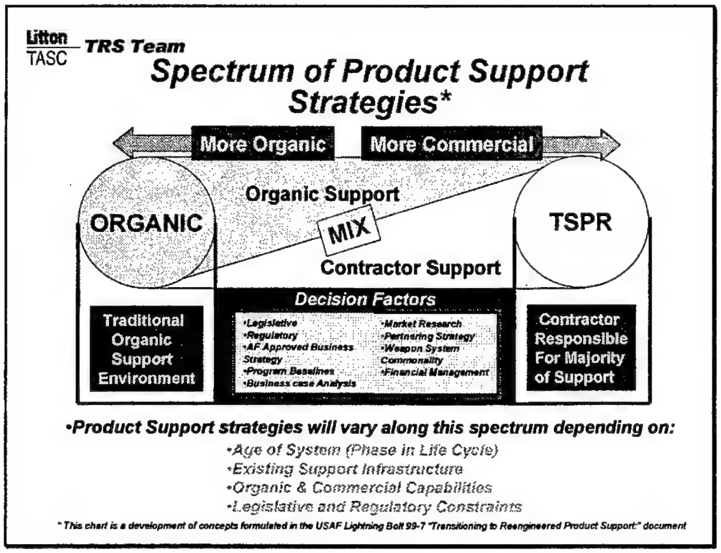
Slide 16



The 15-month study schedule is designed to assure that the TASC/ bd Systems study team has ample time to gather, assess, and coordinate inputs from all sources and review their findings with USAF and supporting organizations.

The products of this study will be used by AFRL/HESS for planning short and long-term research projects in the area of space logistics. The primary thrust of the AFRL/HESS organization is to identify Air Force deficiencies and requirements that fit the mission of AFRL. Additionally, these requirements could be shared with other government developmental agencies as appropriate. Operational requirements identified by the study will be validated within the limitations of the study resources, to assure that AFRL/HESS and other government agencies will focus upon projects offering optimum return on investment to support space operations in a timely, cost effective manner.

Slide 17



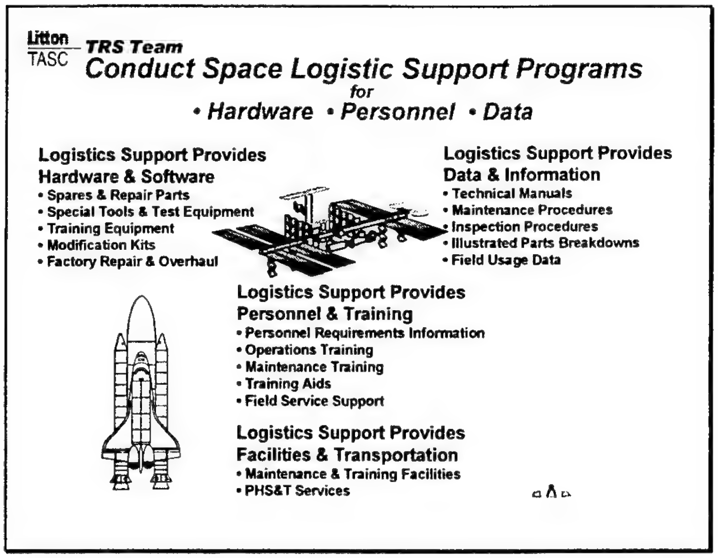
USAF Lightning Bolt 99-7 "Transitioning to Reengineered Product Support"" SAF/AQ, AFMC and AF DSC/I&L examines many aspects of providing Logistic Support to the AF Military systems in the 21st century.

Although this effort focused upon terrestrial and air breathing systems, it does address one of the most critical decisions that must be made for space support, selection of a cost effective source of repair compliant with several key decision factors.

For each level of maintenance of a space system, critical decisions must be made early regarding the planned use of organic and/or some level of contractor sustainment support. The formal source of repair decision is guided by criteria contained in OMB Circular A-76, and promulgated by military service unique directives.

Many of the decision factors considered for incorporation in the LDST are derived from the A-76 decision process. As the LDST becomes populated with data developed during the evolving design maturity of the space system, it can provide source data to the analyst to enable a fair assessment of a broad range of support alternatives including those addressed by OMB A-76 for new and major modifications to space systems.

Slide 18



The implementation of Space Logistics support incorporates the use of hardware, software, personnel, data, facilities and transportation assets. These resources are employed consistent with the approved CONOPS, and are used/consumed to sustain the readiness objectives established by the using command for the space system under development. The support resources illustrated in this chart represents the detailed categories of resource information that are to be explored and documented by the analyst when applying the LDST process.

The elements of logistics shown in this chart will be examined by the study team to identify key considerations and decision factors that should be addressed by the acquisition logistics manager in maturing and executing the support concept and maintenance plans intended to sustain the deployed space system throughout it's life cycle.

APPENDIX A-4
Contact Reports

CONTACT REPORTS

Part of the work of this task is to uncover space logistics deficiencies from which enabling technologies can be identified. In turn, these technologies become the source of near term logistics research programs that the AFRL/HESS can sponsor using 6.3 development funds. Deficiencies found to date are listed below in raw data form.

This is the first modification to the initial DO 12 Logistics System Deficiencies List. This mod adds to the initial list and is the result of the 12 October 2000 Contact Plan meetings and interviews with various organizations at Vandenberg Air Force Base, CA.

CODE:
T = technical deficiency
P = procedure deficiency
M = management issue
C = comment

ACQUISITION LOGISTICS

New acquisitions do not always recognize the 50/50 line and title 10 requirements. This should be done up front and accept the potential impact to sustainment costs. **C**

SOURCE – Audience comments from the Jeff Wampler briefing at Colorado Springs.
Virtual office tool needed to allow all users to keep track of what's going on in a program. **M**

SOURCE – Audience comments to the Terry Jenkins briefing at Colorado Springs.
Output products not always aligned with the acquisition process. All things must be identified. **M**

SOURCE – same as above.
Need to build screens to mine data that is already available. **T**

SOURCE – same as above.
Security not always maintained regarding data used in things such as models. **P**

SOURCE –MILSATCOM, Colorado Springs.
Need on line access to maintenance planning elements to help decision process. **T**

SOURCE – same as above.
Capability not always present to show and defend the decision process that led to a support concept that was not compliant with the 50/50 rule and other requirements. **M**

SOURCE – same as above.

Need more influence on the support concept and how it's developed during acquisition. **C**

SOURCE – same as above.
Acquisition Loggies sometimes fail to consider the back end of the program sustainment activities or consider them incorrectly – especially costs. **M**

SOURCE – same as above.
Need to maintain tech orders for legacy equipment even though they will be TSPR supported. **T**

SOURCE – ESC/ Det 5, Colorado Springs.
Det 5 not sure how they are going to get data for provisioning computation for the space systems and electronics. Currently use RAMS. **P**

SOURCE – same as above.
The Environmental Control System used on the Defense Space Program mobile units should be standardized and modularized for use in multiple space systems mobile units. **T**

SOURCE – DSP/SBIRS (Det 11), Colorado Springs.
When new acquisitions are programmed, 3400 money not always considered in the decision making process, consequently they are always playing catch up. **C**

SOURCE – Space Lift Ranges, AFSMC, Colorado Springs.
Det 11 personnel not always able to obtain maintenance data on TSPR contracts. **M**

SOURCE – DMSP, AFSMC, Colorado Springs.
Structured Integrated Logistics Support process is not always used effectively as part of the systems engineering approach to acquiring military systems. **P**

SOURCE - Bob Dellacamera.
Need to ensure that all logistics tasks in the acquisition phase are accomplished to allow design, development, production and procurement of Air Force Space Systems. **P**

The acquisition logistics deficiencies obtained during the visit to VAFB are listed below:

SOURCE – AFSMC/Det 9.
There is a big issue at VAFB as to what to do with the launch pads and stands that are going to be deactivated as a result of phaseout of the Titan, Delta, and Atlas programs. Most of the problems are property disbursement and environmental. **P**
There is a large effort to get ready for the forthcoming EELV launches. Many of the problems have to do with base support, housekeeping, safety, and security. **P**

Make sure the any modeling has a business decision component as well as technical and scheduling components. **M**

SOURCE – AFSMC/Det 9 (SMC/CLV).
EELV launch vehicles and launch costs must be driven lower than the present "fly-out" systems (Titan, Atlas, Delta). At the same time launch reliability, while presently very good, should be improved. **P**

SOURCE – bd Systems, Det 9.
Currently there are no standards or commonality functions between launch vehicles, their assigned launch pads, support equipment, or processing methods. This is wasteful of manpower and money. A lot of the launch site equipment, on all programs, is either obsolete or very old. **P**

SOURCE – AFSMC/Det 9 (SMC/CLV).
The new VAFB launch pads are being constructed for 30 years capability. They must be able to be converted quickly to commercial launches. Issue is how to invest in new pads reliability, maintenance, growth, and affordability. **T**
Logistics decisions are driven by launch readiness requirements, training requirements, and schedule; not so much technology enhancements. **C**

SOURCE – bd Systems, Det 9.
Many VAFB problems exist as a result of contractual, jurisdictional, and prioritized responsibility issues between the host base and the contractors. The conflicts include environmental, security, fiberoptics ownership, privatization, safety, and general control of base operations. Can anything be incorporated in the LVST to help sort out decisions for these issues? **P**
The differences between leased and licensed facilities and properties have caused a whole new set of contract problems that involve acquisition logistics. **C**
VAFB will be compelled to conduct risk management tasks in addition to just risk management identification problems. The organization charged with risk management will depend on who is responsible for successful delivery of payloads to orbit. **M**

SUSTAINMENT LOGISTICS

Deficiency in the understanding of the information systems problems of government vs. contractor databases. **M**

SOURCE – Audience comments on the AFMSC/Det 11 Commander intro, Colorado Springs.
The real sustainers not always involved up front, especially in a new program. **M**

SOURCE – Audience comments on the Jeff Wampler presentation, Colorado Springs.

The following from audience participation during the Terry Jenkins briefing, Colorado Springs.
Need model to be a virtual tool so it is accessible to AFSPC-SMC-DET 11. **T**
Need to keep model current. **P**
Model must be capable of working on partial data, can't wait until all the blocks are filled in. **T**

SOURCE – MILSATCOM (AFSMC/Det 11) Colorado Springs.
Other services, maintenance data is not available to USAF, therefore not able to perform failure analysis for non-USAF user systems. **M**
The continuously changing configurations of the newer generation spacecraft and ground elements are a primary challenge to the sustainment community. **M**
Need to provide a means to manage CM databases. **P**
Configuration updates accomplished by the user and development agencies are not being properly captured, updated and applied in crew and maintenance training and tech data. **P**
Deficiency in support system data networks, especially near the "front lines." **P**
Currently no logistics support program for the new SBIRS try-antenna design. **P**

SOURCE –DSP/SBIRS (AFSMC/Det 11) Colorado Springs
First, Second and Third Space Launch Squadrons used three different maintenance data collection systems. Need to integrate and simplify. **P**

SOURCE - DET 8 and DET 9, Colorado Springs.
Deficiency in finding an economical way of data mining of the contractor's maintenance databases. No contractual means to get contractor to provide specific data. **T**

SOURCE – same as above.
Any modeling should incorporate " a wizard" support methodology to aid the user. **T**

SOURCE – AFSPC/LGX, Colorado Springs.
Model should provide access to current labor costs for government grades and ranks, and contractor labor rates. **M**

SOURCE - same as above.
No central database, which provides visibility and status over all the sustainment resources. **P**

SOURCE – AFSMC/CWSR Containment-Space Lift Ranges, Colorado Springs.
Deficiency in mechanical and electrical equipment for corrosion control. **P**

SOURCE – same as above.
Problems exist in importing contractor CDA-MDC data into CAMS-REMUS. **P**

SOURCE – AFSCM/CSS, Colorado Springs.

Maybe a proprietary software problem in a couple of areas. **C**

SOURCE – same as above.
SMC/MCL has no basic plan or formula for performing their logistics work. **C**

SOURCE – MILSATCOM (AFSMC/ML).
A deficiency is defining and sustaining commonality between organizations and services as pertains to the terminal staffing and operations. **C**

SOURCE – same as above.
Deficiency exists on SBIRS in that there is a need to develop a simulation for crew training using 5 or 6 consol positions. No simulator exists that fulfills this requirement. **T**

SOURCE - SBIRS/DSP, Logistics Director.
The following deficiencies were derived from review of the DoD, May 2000 Space Technology Guide. This review conducted under DO 12 subtask 3.2.1.2. Air Force management needs to understand, prioritize, and schedule each technical item under 17 below:
Mobile, high precision aerospace ground equipment needed in several places. **T**
Data management and encrypted information processing. Specifically deficient in inventory control. **T**
Need remote, robotic systems to inspect satellite and launch vehicle surfaces while spacecraft and LV are mated at the launch site and in the final stages of launch readiness. **T**
Human factors for using logistics decision support tools. **T**
Standard interchangeable software, electrical, mechanical, thermal, and fluid interfaces for integration, assembly and test activities at launch site. **T**
Advanced diagnostic systems. **T**
Modeling and simulation of maintenance procedures. **P**
Advanced ground based cryogenic handling and storage systems. **T**
Protection from man made radiation. **T**
Advanced tools and algorithms for modeling and simulation. **T**
Automated tech order generation. **P**
High-density, interconnected electronics. **T**
On-board satellite diagnostics detection and damage assessment, with data transmitted to ground sites. **T**
Encrypted inventory systems. **T**
Common protocols for maintenance and repair **P**
On-orbit detection of space environment hazards with information transmitted to ground stations. **T**
Non-intrusive inspection technology at the launch site. **T**
Modular optics for quick on the pad changeout. **T**
Information logistics to support information warfare operations (See Joint Vision 2010). **P**
Intelligent tutoring devices for ground support crew training. **T**

Special case microsat payload integration and launch site processing. **P**
Launch site microsat/launch vehicle preop inspection and special processing. **T**
Launch readiness concepts for formation flying (Microsats) and constellation flights (GPS). **T**
Ground logistics support architecture to accommodate satellite cluster configurations that can easily be changed to perform a variety of military missions. **P**
New ground methods for decontamination from small optics, quick change of damaged structure and lubrication of small critical joints. This item pertains for the most part to micro-satellite operations. **T**

The sustainment logistics deficiencies obtained during the VAFB visit are listed below:

SOURCE – Det 9, AFSMC/CLV.
There are problems in tracking anomalies via telemetry data from launch vehicles and payloads. Need better telemetry monitors. **T**
The sustainment functions include configuration management of the launch vehicle, interface control, and launch vehicle/satellite interconnects. **C**
Three types of sustainment maintenance are performed at VAFB: predictive, on-condition, and preventative. Predictive maintenance procedures could possibly be extended to several launch systems. **T**
The integration process could be speeded up if the launch vehicle and its payload were integrated horizontally. Delta IV will do it this way. It is not planned for EELV. **P**
Need real time, automated, secure method of data acquisition during pre-launch and post-launch operations. Data needed from both the launch vehicle and its payload. **T**

SOURCE – bd Systems, Det 9.
Different programs (Titan, Delta, and Atlas) implement their work breakdown structures to different levels. Thus there is no correlation of time on the launch pad, launch cost, and integration procedures across the various programs. Every launch is a time and material driven operation. Little change in this situation planned for the EELV. **C**

SOURCE – Det 9, AFSMC/ELV.
Recommend a look at a possible universal propellant loading system. Lockheed has one they developed for their own launch vehicles. It is not used on other than Lockheed programs. **T**
Redundant launch pads are not planned. Two pads at each site would provide for launch emergency back up and security. **M**
There is a big deficiency in the quality control work performed at the factory. Factory deficiencies are the source of many problems. **M**
Suggested technology deficiencies include ability to assess the vehicle and payload damage on the launch stand, software to fit any model to prioritize and control launch pad damage. Also need IR technology to detect launch vehicle hot spots and oil leaks, imbedded diagnostic instrumentation to confirm launch readiness, and the above-mentioned propellant loading system. **T**

SOURCE –bd Systems, Det 9.

There is a deficiency in many launch processing procedures for the current EELV launches. Need a new set of processing procedures to meet the goal of limiting payloads on the launch pads to no more than 7 days. **P**

VAFB maybe required to perform launch on demand to support certain NRO missions. **M**

VAFB leadership needs to mature the concept that contractor actions are tracked to focus program management on the system engineering process and to implement quickly and economically corrective actions that are instituted as a result of launch system failures. **C**

SUMMARY

Logistics deficiencies and comments defined to total 85. The breakdown is as follows:

Technical deficiencies = 33
Procedural deficiencies = 26
Management issues = 15
Comments = 11

Deficiency criteria: An item is considered deficient if it can be corrected by machine, device, or equipment or by a procedure, command, directive, personnel change, or more training. A deficient item should be given considerable consideration if it was identified by more than one person, applies to a near term, 2001-3, problem, and affects more than one user, organization, or program. In applying these criteria to the above deficiency list, there is a fine line between technical and procedural deficiencies and management problems. Sometimes a deficiency will be implemented by a management decision but will require considerable technology to be accomplished.

CRITERIA FOR SELECTION TO BE AN AFRL/HESS LOGISTICS RESEARCH PROJECT:

Meets one or more logistics organization's needs (multiple user needs)
Fits AFRL/HESS 2001-03 mission capabilities
AGE improvements, standardization options
Damage assessment and repair
Automated tech order generation
VR for tech dates
Human resources and factors
Show reasonable return for investment and risk reduction
Technology readiness. Is it doable?
Non-duplicative of other research projects
Lends itself to affordable proof-of-concept lab tests and operational demonstrations.
Is it written in the AFRL/HESS budget (about $1M per project per year)?

Can it be a joint research program with NASA, NRO, DARPA, or NRL where feasible for cost sharing?
Application of the research project has growth potential for application to down stream logistics concepts
Research project is safe to conduct
Is the research project mission enabling? Must we have it? Is it essential?

THE DETAILS ARE IN THE NUMBERS

Related documents to date by bd Systems, Inc:

Action Item No. 9, Task 1 Revision, 31 May 2000
Task 1 Methodology, Task 1, 6 July 2000
Contact Reports September thru November 2000
Logistics System Deficiencies, Modification 2, 18 October 2000
Criteria for Selection to be an AFRL/HESS Logistics Research Project, 28 October 2000
Logistics System Deficiencies Analysis, 1 November 2000
A Compendium of Potential Technology Development Items, 30 October 2000 (in work)

The expression----"the details are in the numbers"-----applies to the Space Sustainment Study for AFRL/HESS. This is especially true for Task 1 of the study. This task will likely generate six to ten space logistics research projects that AFRL/HESS will sponsor starting in early 2001.

The references listed above indicate the paper trail to identify space logistics research projects for the AFRL/HESS, WPAFB, Ohio.

The attached chart shows the flow of numbers as we progressed through the process of collecting information, analyzing it, and then categorization of the results, so we could distill it into a list of space logistics research projects from which AFRL/HESS can select a number of specific projects to carry into the technology phase over the near term (next two years).

CONTACTS/INTERVIEWS

The study strategy of acquiring space logistics information on requirements, deficiencies, technology, and candidate research through visits to appropriate Air Force organizations was worked out and implemented.

Visit and Interview Plan – AFRL/HESS and bd Systems cooperated in generating a plan to visit the Air Force people in the 16 organizations shown in the first box on the attached chart. About fifty-five space logistics people associated with space program offices, space operations, and space launch, were interviewed over the August thru November 2000 time period. To complete the space logistics review, users and

spacecraft developers should be canvassed as well. The in-person interview technique resulted in a significant amount of useful space logistics information for near and far term Air Force projects.

Interview Questionnaire – The AFRL/HESS and bd Systems team developed a multi-part series of questions and several briefing documents to facilitate the interviews. The question categories were logistics operations, technology, support equipment, and facilities, modeling and simulation. We also had a category for general information.

The above data collection is still on going as some of the people initially interviewed are being recontacted for additional information and as new contact opportunities are uncovered. All the raw data from the contacts was, or is, being analyzed and fitted into study results. In addition to data received, we found, in these interviews, a good deal of interest for advanced space logistics ideas, processes, models, and equipment as well as a general endorsement of the Sustainment Study objectives.

LOGISTICS DEFICIENCIES

The second box from the left on the attached chart relates to the deficiencies collected so far by the Contact Plan. The deficiencies were first listed under the headings Acquisition and Sustainment Logistics. They were then assigned to the sectors of: technical, process and management. Some so-called deficiency statements were general or administrative in nature – we labeled them as comments. No interview information was discarded or ignored. The numbers show as follows:

Technical Deficiencies	35
Process Deficiencies	21
Management Deficiencies	13
Comments	11
TOTAL	**80**

These 80 deficiencies, Reference 4, were the basis of analysis for logistics requirements and technology needs.

DEFICIENCY ANALYSIS and TECHNOLOGY DEVELOPMENTS

Reference 6 presents the results of analyzing the about 80 space logistics deficiencies. We first separated the 35 technical deficiencies into 10 broad technology areas and then determined what specific enabling technology applications are required to be applied or developed to permit the Air Force to meet the logistics need implied in the deficiency. The 10 technology areas are:

1. Data generation
2. Environmental control
3. Facilities
4. Simulation and training
5. Aerospace ground equipment
6. Inspection and damage assessment
7. Launch vehicle payload integration
8. Telemetry
9. Microsat processing
10. General

Next we separated the 21 process deficiencies into 8 broad technical areas. They are:

1. Security
2. Data management
3. Schedule
4. Facilities
5. Operations
6. Administration
7. Modeling
8. Microsats

The 13 management deficiencies fell into 4 broad areas:

1. Networking
2. Decision Process
3. Operations
4. Cost information

The 11 general comments were essentially repeated, in reference 6, from the specific interview of source. We are almost certain command levels are aware of the content and background of each comment. For the most part, the comments do not lend themselves to resolution by specific technology application.

OTHER TECHNOLOGY SOURCES

Outside the Space Sustainment Study, two other sources of technology development applicable to space logistics are worth noting.

DoD Space Technology Guide, April 2000 – This draft document contains a number of enabling technology projects over 9 Air Force functions that will contribute to space logistics advancement. Please see the bd Systems, Subtask 3.2.1.2, titled Review of DoD May 2000 Space Technology Guide for Logistics Requirements. We identified 50 technologies in this document as applicable to space logistics.

Orbital Express – The DARPA Orbital Express program which started multi-contractor, 14-month parallel studies in October 2000 will provide results of interest to AFRL/HESS. Three prime contractor teams will develop on-orbit servicing system mission concepts. This is a space operations architecture advanced technology demonstration program designed to prepare the way for establishing a routine, cost effective, autonomous capability for the resupply, upgrading, refueling, and reconfiguration of on-orbit spacecraft in the post 2010 timeframe.

This program could offer a possible opportunity for joint AFRL/DARPA logistics research sub-projects that will enhance space logistics.

LOGISTICS RESEARCH PROJECTS SELECTION CRITERIA

The third box on the attached chart shows the criteria we have judged as pertinent to the selection of candidate AFRL/HESS space logistics projects for near term start. The basis for the criteria list on the chart was established early in the study, Reference 1.

The 11 items that collectively comprise the criteria are, in our judgment, specific enough to lend themselves to quantitative analysis, yet general enough to include a wide range of research subjects.

Any research project selected by AFRL/HESS for implementation should show relevance to all 11 criteria. Failure to do so for any one criteria should disqualify the projects.

CANDIDATE LOGISTICS RESEARCH CONCEPTS

The fourth box on the chart contains a list of 13 potential research technology development concepts that resulted from collecting deficiencies and requirements from the USAF Space Systems development, operations, and sustainment organizations during the conduct of the Space Sustainment Study for the AFRL/HESS. It should be recognized that the projects listed by and large were not simply stated by the canvassed organizations but were derived by careful analysis and validating of their needs, then comparing them with the capabilities and interests of AFRL/HESS.

Each of the 13 candidate logistics research projects is described in the next section in brief write-ups giving for each: the title, objective, scope, Air Force organization(s) requiring the capability, approach to the project implementation schedule, and expected results, and resources required to complete.

After AFRL/HESS selects the projects from this list of 13, or others of their derivation, bd Systems will fully develop the rational, task networks, and program plan for implementing each selected project.

One input to this work will be a risk-based approach for assessing project transition. A process rating system will be employed, in this assessment, to determine the consequence of the impact of risk areas on project performance, schedule, and cost.

REFERENCE: Logistics Systems Deficiencies List, Modification 2, 28 October 2000

The bd Systems 28 October 2000 Logistics System Deficiencies List (Modification No. 2) identified 69 problems and 11 comments pertaining to Air Force logistics systems.

This deficiencies analysis is part of the process to associate technology developments with identified problems as precursor to recommending a program of near term research projects that AFRL/HESS could sponsor over the next two years (2001-02).

First some definitions:

Technical deficiency is one that can be corrected by hardware or software.
Procedure deficiency is one solved by a model, sequence or protocol change, new data processing system, different training, manpower assignments, schedule revision, input/output revisions, or insertion of different criteria.
Management problem is one fixed by a command, directive, order, or revision of requirements or criteria for success.

The actual differences are sometimes very small between technical, procedural, and management deficiencies. There were cases where an item was declared to be a management issue but requires a heavy amount of technology to actually correct the deficiency.

The eighty space logistics system of deficiencies and comments, acquired via the study Contact Plan, were listed in the Reference document. They were each annotated as a technical, procedure, or management logistics deficiency or labeled as a comment on some problem.

Most of these deficiencies or comments came directly from the person or the organization contacted, but a few of them were derived by the bd Systems team from the acquired information.

The technical, procedure, and management deficiencies and comments were then categorized and analyzed. The results are presented below.

TECHNICAL DEFICIENCIES – The 35 designated logistics technical deficiencies were separated into the 10 categories below, then the enabling technologies required to correct the deficiencies in the category were added.

Category: DATA GENERATION
Deficiencies:
Mine available databases
On line access to maintenance planning
Maintain technical order
Model partial data capability
Model "wizard" support needed
Encrypted data management and information processing
Automated, secure data required
ENABLING TECHNOLOGY APPLICATION:
Information processing, human factors, advanced tools and algorithms, encryption, computer graphics, data fusion with multi-level security, computer programming.

Category: ENVIRONMENTAL CONTROL
Deficiencies:
Standard DSP type mobile control system
Protection from man-made radiation
On-orbit detection of space environmental hazards (data transmitted to ground)
ENABLING TECHNOLOGY APPLICATION:
Integrated sensors/control technology, heating and air conditioning, human factors.

Category: FACILITIES
Deficiencies:
Pads constructed at VAFB should be designed for a 30-year life
Pads should be convertible to commercial launches
ENABLING TECHNOLOGY APPLICATION:
Construction, environmental impacts, access and security, geology and seismology, civil engineering, radiation hardening, and human factors.

Category: SIMULATION AND TRAINING
Deficiencies:
SBIRS crew training simulator
Modeling/simulation new procedures
Intelligent tutoring devices
ENABLING TECHNOLOGY APPLICATION:
Virtual reality, digital electronics, data processing, display, and controls, software management, automated reasoning, neural networks.

Category: AEROSPACE GROUND EQUIPMENT
Deficiencies:
Mobile, high precision AGE
Universal propellant loading system
Ground-based cryo handling and storage equipment
ENABLING TECHNOLOGY APPLICATION:
Mechanical engineering, electronics, fluid mechanics, cryo technology propellant tankage, human factors.

Category: INSPECT AND DAMAGE ASSESSMENT
Deficiencies:
Remote inspection of surfaces
Advanced diagnostics with data transmitted to control stations
Non-intrusive inspection
Optics decontamination
Quick change of damaged structures
Software to prioritize launch pad damage
ENABLING TECHNOLOGY APPLICATION:
Sensors, robotics, electronics, instrumentation, displays, detector devices.

Category: LAUNCH VEHICLE PAYLOAD INTEGRATION
Deficiencies:
High-density interconnected electronics
Quick optics changeout on pad
Lubrication of critical joints
Detect hot spots
Detect leaks
ENABLING TECHNOLOGY APPLICATION:
Robotics, sensors, modular optics, testing, calibration, integrated situation assessment tools, self-aware/healing networks.

Category: TELEMETRY
Deficiencies:
Tracking anomalies via telemetry
On-board launch vehicle and payload data recorder with information transmitted to ground terminals
ENABLING TECHNOLOGY APPLICATION:
Instrumentation, communications, sensors, on-board data processing, secure transmission systems.

Category: MICROSAT PROCESSING
Deficiencies:
Special techniques for launch site microsat processing
ENABLING TECHNOLOGY APPLICATION:
Microelectronics, unique data management scalable/fault tolerant flight computer.

Category: GENERAL
Deficiencies:
Predictive maintenance interfaces
On-condition maintenance interfaces
Preventative maintenance interfaces
ENABLING TECHNOLOGY APPLICATION:
Logistics planning and engineering.

PROCEDURAL DEFICIENCIES - The twenty-one designated Logistics Procedural Deficiencies are listed below in eight categories. Generally, they require management decisions or changes in process flow to provide resolution. Some of the cited deficiencies are linked to computer modeling or matrix analysis.

Category: SECURITY
Data already in models or in process to be placed into models is not always secure.

Category: DATA MANAGEMENT
Acquiring data for provisioning computation for the appropriate space system and its electronics.

Keeping models current with schedule and flight configuration.
Labeling of configuration management data.
Maintaining technical orders for legacy equipment.
No central database to provide visibility and status over all sustainment resources.

Category: SCHEDULE
Insure all logistics tasks in both the acquisition and sustainment phases are accomplished per the program schedule.

Category: FACILITIES:
What to do with the VAFB launch pads that are going to be deactivated as a result of phase out of the Titan, Delta, and Atlas launch vehicle programs.
Getting ready for the EELV launches. Problems have to do with base support, housekeeping, safety and security.

Category: OPERATIONS:
Future EELV launches must show a lower launch cost than the present "Fly-out" systems.
Currently there are no standards for commonality functions between launch vehicles, their assigned launch pads, support equipment, or processing methods.
First, Second, and Third Space Launch Squadrons use three different maintenance data collection systems.
Mechanical and electrical equipment and processing for corrosion control is deficient.
Need common protocols for maintenance and repair across all systems.
Need logistics to support information warfare operations.
Special case microsat payload integration and launch site processing.
Need ground logistics support architecture to accommodate satellite cluster configurations that can easily be changed to perform a variety of military missions.
The integration process could be speeded up if the launch vehicle and its payload were integrated horizontally. Understand it is not planned for EELV.

Category: ADMINISTRATION
Deficiencies in many launch processing procedures for the current and EELV launches.
Need a new set of processing procedures to meet the VAFB goal of limiting payloads on the launch pads to no more than 7 days.

Category: MODELING:
Need updated set of models for maintenance and repair protocols across all programs.

Category: MICROSATS
New launch readiness concepts needed for microsats formation flying and constellation missions.

MANAGEMENT DEFICIENCIES – The 13 management deficiencies or issues are listed below under four categories.

Category: NETWORKING
Real sustainment people are not always involved up front, especially in a new program.
Virtual office tool needed to allow all users to keep track of what's going on in a program.
Output products not always aligned with the acquisition process. All things must be identified.
Personnel not always able to obtain maintenance data on TSPR contracts.

Category: DECISION PROCESS
Capability not always present to show and defend the decision process that led to a support concept that was not compliant with the 50/50 rule and other requirements.
Acquisition logisticians sometimes fail to consider the back end of the program sustainment activities or consider them incorrectly – including costs.

Category: OPERATIONS
VAFB may be directed to conduct risk management tasks in addition to identification of just risk management problems. The organization charged with risk management will depend on who is responsible for successful delivery of payloads to orbit.
Other services maintenance data is not always available to USAF, therefore unable to perform failure analysis for non-USAF user systems.
The continuously changing configurations of the newer generation spacecraft and ground elements are a primary challenge to the sustainment community.
Redundant launch pads are not planned at VAFB. Two pads at each site will provide for launch emergency back up, security, and concurrent launching of military and commercial (foreign) payloads.
Big deficiency in quality control work performed before the launch vehicle and payload are delivered to VAFB.
VAFB may be required to perform launch on demand to support certain National Reconnaissance Office payloads.

Category: COST INFORMATION
Business model should provide access to current labor costs for government grades and ranks, and contractor labor rates.

COMMENTS: The eleven comments from the referenced document are repeated below. They are general in nature and directed at management for further (if any) action. We are almost certain command levels are aware of the content and background of each comment. For the most part, the comments do not lend themselves to resolution by specific technology application.

All eleven comments are close to direct quotes. The source is not identified here but can be traced via the referenced document. Comments below:

New acquisitions do not always recognize to 50/50 line and title 10 requirements. This should be done up front and accept the potential impact to logistics sustainment costs.
Need more influence on the support concept and how it's developed during acquisition.
When new acquisitions are programmed, 3400 money not always considered in the decisions process, consequently they are always playing catch up.
Logistics decisions are driven by launch readiness requirements, training requirements, and the schedule; not so much technology enhancements.
The deficiencies between leased and licensed facilities and properties have caused a whole new set of contract problems that involve acquisition logistics.
There may be proprietary software problems in several areas.
SMC/MCL has no basic plan or formula for performing its logistics work.
A deficiency is the defining and sustaining commonality between organizations and services as pertains to the terminal staffing and operation.
The sustainment functions include configuration management of the launch vehicle, interface control, and launch vehicles/satellite interconnects.
Different programs (Titan, Delta, and Atlas) implement their work breakdown structures to different levels. There is no correlation of time on the launch pad, launch costs, and integration procedures across various programs. Every launch is time and materials driven. Little change in this situation is planned for the EELV.
VAFB leadership needs to mature the concept that contractor actions are tracked to focus programs management on the systems engineering process and to implement quickly and economically corrective actions that are instituted as a result of launch system failures.

STUDY TEAM Observations ON THE COMMENTS: **As a matter of observation, the above comments reflect space logistics budgetary: contractual, legal, precedent (how it was done in the past), logistics requirements set by the SPOs, security, and proprietary rights in today's economic and political environment.**

In some respects, space logistics, as practiced by the USAF, is in transition. In its FY2000 National Defense Authorization Act, the Congress asked the DoD to develop a detailed guide for investment in space science and technology, and planning and development for space technology systems. The goal is to identify the technologies needed to take full advantage of space for national security purposes.

The Department is currently responding to this request. When this work is completed in early 2001, the results, together with further developments in spacecraft and launch vehicle technology, will certainly modify our current concepts of how space systems are built, tested, and launched. Innovative space system logistics advancements will parallel spacecraft and launch vehicle advancements.

It will be interesting to update this Space Sustainment Study next year to note, at that time, the space logistics deficiencies and comments and to record the forward progress of space sustainment.

APPENDIX A-5
Study Concepts
Recommended Research Projects

RANKED RESEARCH CONCEPTS

CONCEPT	AF Payoff	Customer Reqmt	AFRL/HES Mission Fit	Trans. Potential	Technical Innovation	Risk	Technical Safety	Jointness	Total	Rank
Mobile Facility ECU Core Module	16.43	17.86	7.86	9.71	11.43	11.14	5.14	6.00	85.57	8
SBIRS Crew Trainer	13.57	12.14	13.57	12.00	12.00	9.43	5.71	4.29	82.71	11
Propellant Loading Equipment	15.71	17.14	13.57	10.29	9.71	9.00	6.86	4.57	86.86	6
Remote Surface Inspector	12.14	13.57	12.14	9.14	13.14	7.71	4.86	4.29	77.00	15
Launch Readiness Assessment Tool	13.57	14.29	15.00	10.86	14.86	10.29	6.00	5.71	90.57	4
Optics Decontamination	13.57	14.29	11.43	9.14	14.29	8.57	6.57	4.57	82.43	12
Leak & Hot Spot Detector	14.29	12.14	10.71	8.00	13.71	7.71	6.86	4.29	77.71	14
On-Board Data Recorder/Telemetry Package	17.14	12.14	10.71	9.71	13.14	10.29	6.29	5.14	84.57	9
Microsat Launch Processing	18.57	13.57	14.29	12.57	14.29	11.57	6.29	5.71	96.86	3
Constellation Logistics Architecture	15.00	12.86	13.57	11.43	13.14	10.29	5.14	5.71	87.14	5
Commonality Assessment	15.00	15.71	12.14	12.00	9.14	11.57	5.14	5.43	86.14	7
EELV Model & Simulator, Integration/Test	15.00	13.57	10.00	9.14	9.71	10.29	5.14	5.71	78.57	13
Launch Pad Damage Assessment	18.57	13.57	12.86	10.86	8.57	9.43	5.71	4.57	84.14	10
Logistics Decision Support Tool	20.71	24.29	20.71	17.71	13.14	12.43	4.86	7.71	121.57	1
Maintenance Data Collection Enhancements	22.86	21.43	18.57	14.29	11.43	12.00	5.71	5.71	112.00	2
AFL/HESS Weighting Factors included in Calculations	5	5	5	4	4	3	2	2		

Priority 1. Logistics Decision Support Tool (LDST) Advanced Demonstration

Objective

The principal objectives of Acquisition Logistics are to ensure that support considerations are an integral part of the system's engineering process, that the system can be cost-effectively supported throughout its life-cycle, and that the support resources (products and services) required to support of the system are identified, developed, and acquired. To this end, numerous analysis and decision support tools, some redundant in terms of functionality, have been developed to support program offices, and particularly logistics managers[1], acquire support for weapon systems. For instance, there are several DoD, joint, and component developed cost models in existence for deriving weapon system life cycle cost estimates (e.g. LCCA), conducting network level repair analysis (e.g. NRLA) as well as numerous logistics models and analysis tools developed by specific programs to support their own unique tasks and program requirements. While these models and tools can be very helpful to a logistics manager by "automating" or streamlining specific analyses and documentation requirements levied on program offices to support acquisition and milestone decisions, none of these models or tools directly support a rigorous assessment of program and DoD key decision factors that can have long term impacts on the sustainment of space systems. The purpose of LDST is to help logistics managers and stakeholders responsible for developing and fielding supportable space systems address this shortfall by providing a tool to help acquisition logistics managers conduct and document a more structured and rigorous assessment of key decision factors impacting the acquisition and long-term sustainment of space systems.

Deficiencies

- There are no existing tools that directly support AFSPC Acquisition Logistics managers in assessing the impact of program requirements on contract requirements and critical decision factors related to system supportability.
- No structured, standardized process to assist AFMC and AFSPC logistics managers perform a structured, traceable, and integrated analysis of alternative logistics support concepts.
- Limited pool of acquisition logistics management expertise.
- No automated way to document or assess how key logistics decision factors are addressed across AFSPC and other DoD space programs.

Enabling Technologies

- Artificial Intelligence (Rules-based, expert systems).
- Knowledge Management.

[1] "Logistics Managers", as referenced in this report, includes personnel responsible for managing and acquiring specific logistics products and services for a weapon system – e.g. technical data.

Scope of Research

The primary goals of this research task is to build an advanced demonstration of the LDST based on the framework and design concept developed and proposed for LDST through research accomplished as part of the *Space Logistics Front-End Analysis* task. This task extends the research for LDST through the design and development of a robust demonstration of the LDST framework that clearly shows all the critical components (including inputs and outputs) and technologies comprising an expert-based tool that can significantly improve the process for conducting timely, accurate, and defendable logistics supportability analyses for space systems.

Research Tasks

1. Conduct an LDST knowledge engineering analysis (e.g. cognitive task analysis, etc) required to capture and model the required decision factors and inference rules; input requirements; and outputs for the LDST.
2. Design and develop the main components of an LDST knowledge base to include decision factors, inference rules for applying decision factors, etc.
3. Develop and demonstrate the main components of an LDST database required to support LDST user and project administration activities, including the input of baseline program and system requirements, constraints, etc.
4. Develop and demonstrate the capability for a space logistics "expert" to update LDST decision factors and rules in the knowledge base through an intuitive user interface.
5. Develop and test LDST demonstration software.
6. Prepare LDST software documentation.

Research Products

- Technical Reports documenting the LDST design (high level and detailed); development, testing, and transition requirements.
- LDST Advanced Demonstration.

Potential Benefits

- Improving the process for developing and evaluating logistics support concepts for current (modifications and upgrades) and future (new acquisition) space systems throughout a program's life cycle by providing a structured approach for addressing and responding to key decision factors, and provide the capability to document and rapidly recall the rationale for the same.
- Assist novice acquisition and sustainment logistics managers focus on the key decision factors and related questions they must respond to and/or answer as part of the planning process for developing and executing a support concept and plan, thereby reducing user misdirection due to incomplete information and thereby reduce the overall logistics workload requirements to operate and sustain space systems.
- Help ensure that acquisition logistics and logistics support decisions are made in a more a consistent, informed manner across current and future space systems programs.

- Retain the AFMC and AFSPC organization's expertise in a readily maintainable form (an "expert" system should be able to maintain currency with rules in the knowledge base as logistics policies and procedures evolve).
- Address the need to capture, and enhance critical corporate knowledge from both acquisition logistics and sustainment logistics "experts" who are leaving the workforce in the near future. This is a key DoD concern, particularly in the USAF, which estimates that up to 60% of the current civilian workforce will be eligible to retire by the end of 2005.
- Provide an audit trail for key decision factors related to the analysis and determination of system support requirements.

Potential Barriers/Risks

- Identifying and obtaining participation from "expert" logistics managers in AFMC and AFSPC.
- Time required (including logistics experts, knowledge engineers, users) to acquire business rules and complete knowledge engineering activities, including development of high-level user interface designs for LDST.
- Providing a dynamic capability for "expert" logistics managers to update the LDST knowledge base in response to changes in program and DoD policies and procedures.

Potential Users

Transition Agent:	SMC, LAAFB (it is envisioned that an LDST server would reside at SMC)
End Users:	SMC/AXL and acquisition logistics managers assigned to SMC system program offices responsible for assessing program and system requirements in order to derive alternative support strategies, develop RFP inputs, etc.
	HQ AFSPC/LGX/DR and AFSPC wing-level logistics personnel for reviewing and providing inputs related to the assessment of key decision factors impacting system support requirements
	Ogden ALC (OOALC/LH) Space Systems managers and analysts to assess and update/adjust decision factors used in identifying and quantifying support resource requirements based upon actual field requirements for new space systems, and to update decision factors used in identifying modification requirements to legacy systems

Estimated Timeframe
It is estimated that an LDST system, which could be demonstrated and transitioned for initial use by AFSPC (including documentation), would take between 12 to 14 months to design, develop, test, and deliver.

Estimated Cost

R&D Cost	$575K (Including Travel)
Transition Cost	(Included as part of R&D cost)
Yearly Maintenance Cost	$50K

Return on Investment
An initial LDST ROI analysis was accomplished to include the estimated costs for development of a robust demonstration system that could be transitioned to SMC (and or AFSPC) for initial application to space system sustainment planning and analysis. The cost to perform the study is estimated at $575K with a 12 to 14 month development effort. This estimate could be scaled downward depending upon the number and depth of Integrated Logistics Support (ILS) elements that are actually implemented in the LDST. The estimate shown above considers that all ILS elements would be incorporated into the LDST design, and a $50K cost for yearly LDST maintenance and update beyond the initial development effort. The dollars shown above and in Figure X-XX below were derived from estimates provided by SMC/AXL for performing the initial cost-benefit analysis. The central cost benefits accrued to the LDST users from application of an LDST to space system support and sustainment planning and analysis include:

Training
30% reduction in training time for new Acquisition Logistics personnel pursuing Level II certification (assume 10 year military/GS civilian years experience in related disciplines; average grade is a Captain, 0-3/GS-10/11).

Reduced Time for Performing Contract Requirements Analysis
A 25% reduction in analysis time is estimated. The study team assumed that most of the analysis that LDST could support during the acquisition phase of a new space system would be performed primarily prior to and during the EMD acquisition phase (i.e. review and refinement of ORD requirements, and update/expand maintenance concept(s); assess critical decision factors and space system sustainment requirements for RFP inputs, etc).

The baseline for performing a comparable analysis without an LDST was estimated to take approximately 12 months to complete the "analysis" process. Use of an LDST is expected to reduce this timeline by three months. It is further estimated that approximately six AFSPC programs per year (including major modifications), with an average of one Acquisition Logistics manager assigned to support each program, would also derive cost saving benefit from application of an LDST.

In conclusion, it is estimated that an initial investment in developing an LDST system would start paying back significant cost savings following a 3-year development, and training/introductory period.

Priority 2. Space Systems Maintenance Data Collection (MDC) Enhancements

Objective

Maintenance Data Collection (MDC) is an essential part of the processes used by all Air Force operational units to help identify, justify, plan, and program the sustainment and modifications for weapon and space systems. The Core Automated Maintenance System (CAMS), and Reliability and Maintainability Information System (REMIS) are two of the primary reporting systems used by the United Stated Air Force (USAF) to execute these processes across all Major Commands. The CAMS and REMIS systems are continuously being upgraded in terms of hardware and software to streamline and otherwise improve the efficiency of the MDC reporting system. These include enhancements to the user interfaces, databases, etc. that comprise these systems.

Although these and predecessor maintenance data systems have been in existence for many years for the MDC process, not all USAF bases or units have experienced "ready" access to systems like CAMS since it's inception. This has created problems and inconsistencies in the type of data collected by AFSPC maintenance units, and the manner in which the field problems are reported up the chain of command. These problems are being resolved, or are close to being resolved for most Air Force major commands (MAJCOMs) through the development of the Integrated Maintenance Data System (IMDS). However, a lingering problem still exists within Air Force Space Command (AFSPC)caused by inconsistent and inaccurate MDC reporting by several maintenance units of the command using CAMS and REMIS. A few exceptions have been noted, however, that shows some AFSPC wings and units simply seem to do a better job of recording and tracking MDC data.

Historically, the benefits that accrue to the units that successfully capture and report accurate MDC data is that the data, when properly analyzed and summarized, will provide quantified, factual data that help the command justify and receive funding for hardware and/or software modifications and other improvements for the space system operated and maintained by the reporting unit. Additionally, it is common knowledge that MAJCOMs that can gather accurate, effective MDC data with which to justify hardware and software improvements or replacement are able to compete more effectively in the POM process to capture limited sustainment dollars. HQ AFSPC/LG has recognized this problem and is vigorously working to improve MDC reporting at all of their operational wings and units. The issue that appears not to have been specifically addressed in any previous research related to MDC reporting, is an accurate definition of the specific, and often unique MDC data needed by the AFSPC and AFMC maintenance and sustainment communities to effectively and efficiently support the decision processes used for space system sustainment planning and programming decisions.

Deficiencies

- Inconsistent collection and reporting of MDC data by AFSPC units.
- Access to, and accuracy of MDC data (particularly contractor maintenance data) is deficient.
- No documented relationship appears to exit between the AFSPC MDC reporting process and AFSPC maintenance/sustainment decision processes that conveys how the collected data supports and facilitates AFSPC and AFMC sustainment planning and decision processes.

Enabling Technologies

- Semi-autonomous data search and retrieval capabilities to improve the timeliness and accuracy of MDC data collected by AFSPC maintenance organizations.
- Sensors and data fusion to accurately capture factual and traceable, uptime, failure causes, and maintenance/repair timelines from multiple sources.
- Intelligent Agents to facilitate data retrieval, process monitoring, data fusion, etc.

Scope of Research

The scope of this proposed research task involves performing a broad-based assessment and analysis of AFSPC and AFMC MDC data required to support and facilitate informed space system sustainment and modification decisions. This will include identification of problems that include the following:

1. Identify tools or systems currently used to support the AFSPC and AFMC (OOALC) decision processes associated with space and C3I system sustainment planning and programming.
2. Identify the data that is currently collected through MDC reporting used by AFSPC units, and define specific AFSPC decision processes / tools supported by this MDC data.
3. Identify data currently not collected by the AFSPC MDC reporting process that is needed to improve the ability of AFSPC and OOALC to identify, justify, plan, and program budgets for space system sustainment and modifications.
4. Identify any unique data requirements for space system sustainment that are not supported by the current AFSPC MDC reporting processes and systems.
5. Highlight important differences, if any exist, in AFSPC MDC reporting data for space and related C3I systems versus aircraft systems MDC reporting.
6. Address and define the need for a revamped AFSPC MDC reporting process and/or system to support space systems maintenance, and identify potential benefits, if any exist, to adopting space systems MDC reporting for aircraft maintenance application.
7. Recommend technologies and practices (including commercial) that could improve and/or enhance efficiencies in the collection of AFSPC MDC data.

This recommended research does <u>not</u> include identifying problems that can be resolved through software or hardware improvements to existing systems like CAMS and REMIS, including future systems like IMDS. Further, <u>no software will be designed or developed as part of this research.</u>

Research Tasks

1. Survey current maintenance decision support tools, systems and processes used by HQ AFSPC, OOALC/LH, and SMC system program offices to support planning, programming, and budgeting activities for space and related C3I systems sustainment.
2. Identify the data requirements used with these tools, systems and processes, and compare to the data provided through AFSPC MDC reporting using existing CAMS and/or REMIS systems.
3. Identify shortfalls in AFSPC MDC data reporting through comparative analysis performed under task 2.
4. Document recommendations (including technologies) to streamline and introduce efficiencies in both the collection and reporting of AFSPC MDC data. Recommendations should focus on methods and technologies that will improve the effectiveness of current tools, systems and processes used by HQ AFSPC, OOALC/LH, and SMC system program offices to plan and program sustainment and modifications of space and related C3I systems.
5. Provide recommendations on insertion of new improved methods and techniques to capture space systems maintenance-oriented data from automation systems that function independent of human inputs, or with minimum human inputs.
6. Document study results in a final report.

Research Products

A final report documenting the following:

a. Identification of current tools or systems used by HQ AFSPC, OOALC/LH, and SMC system program offices to plan and program the sustainment and modification of space systems.
b. Define the decision process (tasks and activities) used by HQ AFSPC, OOALC/LH, and SMC system program offices to plan and program the sustainment and modification of space systems.
c. Identify the specific data and data elements used to support (a) and (b).
d. A comparative analysis and report of the specific data provided through current standard USAF MDC reporting processes using CAMS and REMIS and (c) to identify shortfalls in the AFSPC MDC data reporting. This should result in a list of key and unique MDC data required by AFSPC, OOALC/LH, and SMC SPO's.
e. A survey of technologies that can improve the collection and reporting of "key" AFSPC MDC data.

Potential Benefits

- More effective processes for AFSPC MDC reporting that directly relates "space unique" MDC data requirements with "standard" processes, tools, and systems. This improved process would require collection of specific MDC data to support AFSPC planning and programming decisions associated with space system sustainment and modifications.

- Improved processes and techniques for AFSPC MDC data collection and reporting that will reduce the "Warfighter's" maintenance documentation workload requirements.
- Identification of technologies that will improve the accuracy and timeliness of AFSPC MDC data required to support AFSPC, OOALC/LH, and SMC SPO maintenance and sustainment planning and programming decision processes.

Potential Barriers/Risks

- No standard, or consistent process is currently used by all AFSPC maintenance organizations for collecting and reporting AFSPC MDC data from field units or contractors providing sustainment support under Total System Performance Responsibility (TSPR) contracts.
  - No standard, or consistent process, systems, or tools for using AFSPC unique MDC data to support AFSPC planning and programming decisions associated with space system and related C3I maintenance, sustainment, and modifications

Potential Users

Transition Agent:
HQ AFSPC/LGX

End Users:
HQ AFSPC/LGX
SMC Space Systems Program Offices
Ogden ALC, Directorate of Space and C3I (OOALC/LH)

Estimated Timeframe

12 months

Estimated Cost

R&D Cost	225K (including Travel)
Transition Cost	TBD
Yearly Maintenance Cost	TBD

Return on Investment

Some level of effort will be devoted during the proposed MDC research effort to estimate and quantify the time and cost of developing and sustaining the space systems unique MDC device using software estimation techniques such as COCOMO, and relating the output to quantitative benefits that might be expected from AFSPC maintenance units' use of a space unique MDC device to record and report space systems maintenance activities.

As stated in the opening section, the Core Automated Maintenance System (CAMS), and Reliability and Maintainability Information System (REMIS) are two of the primary reporting systems used by maintenance technicians throughout the United Stated Air Force (USAF) to execute Maintenance Data Collection (MDC) on the service's weapons

systems. AFSPC is no exception to this philosophy and the need to fully record and document all maintenance actions taken on maintaining the ground and air-based elements of space systems equipment and software operated by the command. It is estimated by the study team that overall maintenance man-hours used by the AFSPC maintainers to fault isolate and restore systems to operational status could be reduced by a nominal 5-15% with the introduction of a user friendly MDC device specifically tailored for rapidly recording space unique maintenance data.

Assuming an AFSPC maintenance force of 8,000 skill level -3 through –7 technicians, and a productive 1600 maintenance hours/year/technician, the estimated savings could equate to $240,000 - $360,000 per year.

Priority 3. Microsat Launch Site Processing

Objective

Microsat technologies are rapidly evolving to a level that they are now being considered for performing many military space operations previously performed by larger and heavier spacecraft. Microsats have also been shown to lend themselves to space servicing applications and could be designed as Orbital Replaceable Units (ORUs) for in-situ repair or upgrade of conventional satellites using an appliqué technique provided the spacecraft to be serviced is configured to host the Microsat ORU. Additionally, Microsats are also under study for potential deployment in large arrays to function, for example, as communications, weather, or sensor satellites. To successfully accomplish these missions, Microsats must be capable of attaining specified orbital velocities to perform most of these postulated scenarios.

The DoD Space Technology Guide reviewed by the study team cites the government goal for space launch is to reduce the payload and launch vehicle integration costs by a factor of at least 10. The study team firmly believes that for future Microsat launches, application of the launch concepts envisioned by this study could contribute to achieving this national goal. Upon review and assessment of Appendix G of the STG, it is also the opinion of the study team that the Anti-Satellite (ASAT) launch vehicles and trajectories conceptualized in the STG will not provide the necessary launch performance to attain the required orbital velocity. Further, it appears that the Microsat preliminary launch concepts described in Appendix G of the STG do not consider all potential tactical operations and sustainment alternatives.

The objective of this study concept is to devise economical approaches for launch preparation and processing that will result in achievable mission deployments at a reasonable cost. It is conceivable that launch vehicles such as Pegasus, Taurus, and an RLV derivative such as the X-37, or the Space Maneuvering Vehicle (SMV), may also be capable of economically deploying Microsats. To achieve this lift potential, however, considerable modifications must be designed for these launch systems in order to develop a variety of "tactical" capabilities to meet military mission readiness and availability requirements.

Deficiencies

Identified in the following documents:

- DoD Space Technology Guide, Appendix G, Microsat Launch Concepts.
- 2000 Space Support Needs (IPP 04) SS LO-2 & SS-LO-3.

Enabling Technologies

- Agent based technologies could be used to develop Microsat checkout and verification routines and equipment.
- Semi-active monitors.
- Computer aided testing techniques.
- Self-healing software.

Scope of Research

Advanced processing techniques are needed for micro-satellites and launchers if they are to be rapidly deployed in tactical scenarios, and in massive quantities. To employ Microsats in a tactical scenario, a means must be found to minimize launch preparation timelines, labor-intensive processing efforts, and life cycle operations and sustainment (O&S) costs. Current launch processing techniques and technologies, and pre-launch activities are very labor-intensive and much too time consuming to enable rapid response to changing tactical situations. The application of advanced automation technologies for monitoring and conducting pre-launch activities for Microsats offer great promise to significantly reduce the current labor-intensive techniques and processes.

Microsats offer the possibility of launch-on-demand. However, if current launch site activities are not streamlined, the costs to launch the postulated Microsats in the tactical scenarios envisioned could easily outweigh any benefits. To help hold costs to a minimum, Microsats and their launchers could be delivered to the launch site in a "Certified" or "Launch Ready" condition, capable of being stored in facilities with normal environments, and requiring minimal condition inspections, or other labor intensive monitoring and attention. When a Microsat mission is scheduled for launch, the Microsat could be quickly mated to the LV, launched, and orbit attained with little or no impact on the transportation vehicle.

Models currently exist within the Air Force's operational commands that simulate rapid launch operations of both tactical and ballistic missile systems. These models employ a much more simplified mission planning, payload integration, launch site operation, and other pre-launch actions than the current or planned launch processing techniques and methodologies for space systems. The uses of Microsats in the future are expected to include many high frequency missions; therefore, additional automation will be required to monitor and conduct efficient launch preparations and operations.

Timely and responsive sustainment of these Microsat launch activities will require a high performance logistics system to economically sustain the intense pace of postulated tactical launch activities. Many of the techniques currently used in the ICBM model could be extrapolated and enhanced with new technologies then applied for Microsat launches.

Research Tasks

- Form an IPT with AFRL/VS and AFSPC operations and launch organizations to define alternative sustainment approaches for Microsat systems and their postulated launch systems.
- Assess the feasibility of extending ballistic missile sustainment approaches with new technologies and methodologies to the launch vehicles for Microsat systems.
- Work with AFRL/VS to develop concepts for testing program and support equipment that can verify the availability and readiness of Microsat systems.

- Identify technologies that could be adapted/used for "smart" storage monitoring of Microsat condition status, automated certification testing, and develop laboratory prototypes to demonstrate feasibility.
- Formulate a strategic plan that demonstrates viable applications of these technologies and delineates steps required to implement improved Microsat launch sustainment systems.
- Identify methods to optimize existing launch site and basing architectures for Microsat launch operations.
- Derive requirements for a computer simulation model for Microsat mission planning that could be used by tactical unit planners to develop launch procedures for each Microsat mission set.

In conversations with Colonel Jack Anthony (AFRL/SVE) and Major Jim Branson (Air Force Space Battlelab), it was evident that the concept proposed in this paper is not being worked or considered by either of their respective organizations at this time. Major Branson commented that it's conceivable that any Microsat launch concepts(s) resulting from this research could have direct or indirect application to follow-on studies and future on-orbit tests evolving from the Orbital Express studies and demonstrations currently underway by DARPA. Such applications could include, for example, spacecraft inspection via imbedded micro camera to observe and document any anomalies observed during the spacecraft deployment and operation, and/or to identify potential surface damage that may have been incurred during or following launch and orbital insertion.

Research Products

1. Microsat launch system support plan that describes:
   - Operational infrastructure concepts for fielding microsat systems.
   - Methods to rapidly certify Microsat availability and readiness to meet tactical requirements.
   - Transition approach to modify current launch vehicle/single payload preparation techniques and processes to an architecture that efficiently integrates multi-payloads on a single launch vehicle.
2. Requirements for Microsat certification software and test equipment.
3. Requirements for Microsat pre-launch model(s) and simulations to facilitate evaluation of satellite and launch vehicle integration, test, and checkout processes to verify launch readiness.
4. A plan to extend the application of study products/findings with operations concepts for future space-basing of Microsats.

Potential Benefits

The postulated testing software, modeling and simulation products and equipment are within the military current state-of-the-art. These techniques and products have been successfully used for tactical and ballistic missiles but have not yet been integrated into space launch and satellite programs.

It is expected that the findings and demonstrations accomplished by this study will identify specific needs for new technologies such as semi-active monitors; computer aided testing techniques; and self-healing software. With the application of this new technology, efficiencies of the mission operations for Microsat systems could be enhanced, and space systems sustainment will evolve to more closely resemble tactical missile operations of terrestrial systems. This should enable potential synergies and resulting cost savings.

The goal of the Microsat launch project described above is to provide an alternative launch capability specifically for selected Microsat missions, and to contribute to the overall DoD goal of cost reduction and cost avoidance of payload and launch vehicle integration costs, specifically as applied to the launch of Microsat spacecraft.

Potential Barriers/ Risks
No technical barriers are currently known to exist for this study concept. Ample advanced automation technologies are available and in process of emerging that could be readily applied to implement this concept.

The greatest risk is extended delays in accomplishing this research in a timely manner to positively impact the development of Microsat systems. It is expected that the findings and products of this research will greatly influence the way launch processing is accomplished for Microsats and other space systems of the future.

Potential Users

Transition Agent:	AFSPC/SV
End Users:	AFSPC, DO, XP LG AFSPC/SV SMC Launch and spacecraft SPOs

Estimated Timeframe
This initial study concept is estimated for a twelve-month duration. However, this project could become a continuing study effort as the state of the art of Microsat technologies continue to evolve, and as new missions are conceived for the Microsat family of spacecraft.

A follow-on research project could mirror the Microsat development schedule. Initial work would be done on breadboard Microsats and fed back into the design of full-scale production vehicles. Full-scale development would normally be managed by the AFSMC development SPOs. Any software and support equipment required to sustain the Microsat launch concept presented in this paper must also be developed/acquired and be in place to support the training of personnel for IOC and FOC.

Estimated Cost

R&D Cost	\$350K (Includes travel cost)
Transition Cost	Microsat systems are not yet fielded, therefore, no transition costs will be incurred.
Yearly Maintenance Cost	TBD

Return on Investment

The DoD Space Technology Guide (STG) identifies nine classes of military space mission technology areas. These include:

1. Space Transportation
2. Satellite Operations
3. Navigation
4. Command, Control and Communications
5. Intelligence, Surveillance and Reconnaissance
6. Environmental Monitoring
7. Space Control
8. Information Operations
9. Force Application

Each one of these mission areas could be supported either fully or partially by Microsat spacecraft placed into appropriate orbits using one of the alternative launch methods addressed by this research concept for Microsat launches. The initial planning accomplished during this research effort will result in a "strawman" support concept that would serve as a starting point for any of the postulated missions for Microsats.

By creating baseline support concepts for a variety of postulated missions, the costs normally incurred by a SPO or developing contractor in performing studies and analysis to develop preliminary and initial launch concepts, and operations concept plans for specific application to selected Microsat launch applications could be avoided or significantly reduced.

For example, if the initial effort required to perform trade studies to develop launch support concepts for five Microsat mission scenarios could be avoided or reduced during early program development, the estimated cost avoidance could equal up to \$1.75M.

Strawman Launch Site Analysis x Missions = Cost Avoidance
\$ 350,000 x 5 = \$1,750,000

Also the preliminary launch support planning accomplished during this study effort would establish a benchmark for Microsat missions; therefore, the essential supporting elements for these launches will have been identified, developed and ready for tailoring to a specific mission as needed.

Priority 4. Launch Readiness Assessment Tool (LRAT)

Objective

Launch vehicles operating out of government ranges must be certified by government personnel prior to launch, whether government or commercial operations perform the launch. Several launch vehicle contractors make use of advanced techniques to monitor the progress of their launch systems throughout production and integration activities. With the evolution of ELV and eventually RLV launch operations, contractors will have full responsibility and accountability for all pre-launch, launch, and initial orbital deployment processes and activities. The Air Force will no longer maintain full oversight capability during the transition process. The government needs an assessment system that can interface with existing test data to effectively monitor the readiness of the launch system before payloads are committed to launch. Such a capability will provide the responsible Air Force organization with the opportunity to make a timely, independent assessment of space flight readiness and worthiness of any expendable or re-useable launch vehicles that are used to place DoD satellites in orbit.

The Air Force Space Command Operational Safety, Suitability, and Effectiveness (OSS&E) program establishes and preserves baselines for operational safety, operational suitability and operational effectiveness throughout the operational life of a space system and is a requirement for all space systems launched and operated by the command. Individual OSS&E assurance reviews and flight worthiness certifications may be accomplished by either contractors or the government for each launch. Launch operations space flight worthiness criteria ensure that the system is successfully integrated and that the launch operations process is ready. Prior to each launch, the AFSPC Space Flight Worthiness Certification Criteria Control Board verifies that the launch operations space flight worthiness criteria are adequate to assure that the system can be successfully integrated with other major components and performs as designed.

The objective of this study concept is to enhance the ability of the AFSPC to certify and assure space flight worthiness of space vehicles for launch and flight in compliance with the Air Force OSS&E policy and requirements in timely, cost effective manner.

Deficiencies

Inability to acquire and assess relevant data to certify launch readiness for flight in an effective and timely manner.

Cited by:
Lt. Col. Joan Jackson and Staff (AFSPC/LGMS)
Lt Chris Burner (Det 9 AFSMC/CLV)
Lt. Col. Ross Gobel (AFSMC/CWSL)

Enabling Technologies

- Data analysis software using rule based expert systems for evaluating launch vehicle and payload testing.
- Advanced user-interface techniques for the assimilation of disparate data.
- Wireless data transfer technologies.

These technologies will be evaluated to determine utility to help decision-makers in rapidly assessing status of launch vehicle and payload launch preparations.

Scope of Research

Evaluate the feasibility and requirements for implementing an assessment system that will enable Air Force launch organizations to monitor the progress, readiness, and completeness of launch preparations by contractor provided launch services.

Research Tasks

- Review existing contractor systems that are used by the launch vehicle developing contractors and evaluation systems used by the DoD military services for tactical systems.
- Assess government and contractor aircraft production and acceptance test systems for identification of relevant protocols and measurement systems that may have application to space flight worthiness assessments.
- Identify key data that is required for assessing the space flight worthiness criteria of each launch vehicle and the timelines in the launch processing.
- Develop and document a concept for standardizing the assessment process across both expendable and re-useable launch vehicles.
- Explore the use of emerging technologies, such as expert systems wireless data transfer and advanced user interfaces, to aid in rapid assessment of the launch vehicle and payload launch preparations.
- Develop a project plan for the development and implementation of the assessment system.

Research Products

1. Concepts and a plan for implementing a readiness assessment tool that contains:
    - An approach to data analysis software routines that can assess the status of the subject launch vehicles, payloads, and readiness of supporting launch systems.
    - Concepts for a flexible data acquisition system that can interface with, and "Read" critical data used in monitoring performance of the different launch vehicles and telemetry systems.
2. Develop a demonstration system.

Potential Benefits

- Enhance the ability of the Air Force to certify and assure space flight worthiness of space vehicles for launch and flight in compliance with the Air Force Operational Safety, Suitability, and Effectiveness (OSS&E) policy and requirements in timely, and cost effective manner.

- Contribute to a reduction in the manpower requirements (launch processing and inspection workload) on the space launch ranges. (Note that currently both Air Force launch ranges (Western & Eastern) employ approximately 4000 personnel; the current DoD goal is to seek ways to reduce this population by 35% (approximately 300 technicians and engineers).
- Provide a means for data analysis and reduction service to range users (DoD and Commercial) on a cost basis. Potentially, this service could contribute to offsetting launch services costs by roughly $2-3 million per launch.
- Reduced analytical and decision making timelines to certify flight worthiness of space vehicles.

Potential Barriers/Risks

- Proprietary systems used by launch vehicle-developing contractors may not allow the definition of data and interfaces required for the system.
- Access to the interface protocol's with contractor and government telemetry systems.
- Contractual issues. Specifically, EELV contractors are not required to deliver nor otherwise provide the government with data, or access to data that contain the technical information that would enable AFSPC to assess flight worthiness of the launch vehicle to be used to lift a payload to its assigned orbit.

Potential Users

Transition Agent: AFSPC/SMC/CL, EELV SPO

End Users: Launch Vehicle and Spacecraft SPOs, Space Launch Range SPO, HQ AFSPC, and AFSMC Det 8 &9

Estimated Timeframe

Total time: Two to three years. The requirements analysis and planning effort will be a twelve-month effort. The demonstration system could be a (two-year+) development effort.

Estimated Cost

R& D Cost

$300-$500K (Could be less dependant upon availability of and access to contractor diagnostic software). This effort will also provide the refined concept(s) and plan.

Development Cost

Approximately $1M for software and procedural development.

Transition Cost

- Any modifications to government and/or contractor equipment that may be deemed necessary to achieve the concept objective is roughly estimated at slightly under $1 million per range. It is expected, however, that the study will

identify many items of equipment already in place at the range that could perform some or most of the data monitoring. Use of in-place equipment for these functions would reduce the number and types of sets to be acquired and thus reduce the overall amount of transition costs. (NOTE: See study concept #7, Logistics Commonality. This separate concept may provide identification of common test and/or support equipment items that could be considered for this research concept.)

- Transition of new software and procedural changes that will be implemented at each range is estimated at $2-3M.

Yearly Maintenance Cost
Some minimum costs could be associated with providing updates to ranges due to new or changes in legacy launch vehicle checkout procedures, and/or other processes that could impact the decision factors in this tool. Additionally, the introduction of any new launch vehicles and associated checkout procedures/processes could also affect annual maintenance costs.

Return on Investment
Savings estimates given in the "Potential Benefits" section shown above are based upon the study team's knowledge of the space systems and space launch industry, including experience in installation, checkout, and launch of spacecraft for both DoD and NASA customers.

Some level of effort will be devoted during the proposed development effort to estimate and quantify the time and cost of developing and sustaining the LRAT using software estimation techniques such as COCOMO, and relating the output to quantitative benefits that might be expected from the use of an LRAT. With this in mind, applying the study team's knowledge and experience in planning and executing space launches over the past 30+ years, and having knowledge of the nominal resources and timelines usually required, the following return on investment analysis is presented:

- Use of LRAT could be expected to reduce analysis and decision making timelines to certify the flight worthiness of launch vehicles by approximately 15%.

  - During most launches, there are approximately 20-30 technicians/engineers directly involved in the decision process at each of the typical 4-6 military launches every year. The Air Force operates two launch sites: Vandenberg AFB, California and Cape Canaveral AFS, Florida.
  - An estimated savings of from $600,000 to $1,350,000 /year can be achieved for employing this type of enhancement tool in the decision making process as shown below:

    % Schedule Reduced x # Personnel x Avg. Salary x launches/yr = estimated annual savings

    0.15 x 20-30 personnel x $50,000 x 4-6 launches/yr = $600,000 - $1,350,000 /year.

- It is difficult to quantify the assurance that a readiness assessment is accomplished with sufficient rigor and thoroughness to determine with a high degree of confidence that the launch will be successful. Therefore, the study team conservatively estimates that the confidence factor in performing such assessments, with the aid of an automated analysis tool such as LRAT, could be increased by 5-10%.

Priority 4a. Advanced Launch Range Maintenance System (ALRMS)

Objective

An extensive radar complex that is vital to the success of each mission tracks Launch Vehicles operating out of government ranges. There are approximately 22 such sites throughout the world. Each radar site has its own maintenance control function that is not coordinated beyond the site. Radar sustainment contributes to approximately 1/3 of the support problems on the range. Currently, most range fault isolation is done rapidly, but with only very limited automation down to the rack level. This results in the fault detection being narrowed down to only an average of 10 to 20 line replaceable units. Below that level, it is mostly manual fault isolation performed by 9-level, high cost contractor experts using engineering drawings; standard Air Force technical data normally does not exist for the systems operated at the sites. The cost of sustaining this pool of contractor expertise is very expensive. Moreover, the average age of these experts is nearing retirement. The ranges have over 25,000 line replaceable units (LRU's), which is more than an F-16 fighter and are often comprised of only one or two of a kind in the system. Moreover, these LRU's are often lacking standard base supply equivalent logistics support.

A huge workforce of approximately 3700 engineers and technicians currently accomplishes all sustainment activities associated with the eastern and western ranges. The AFSPC goal is to reduce this workforce by 20% (to 3000) by 2010. Additionally, an effort is currently getting underway to modernize elements of the Space Lift Range System will be provided by the Space Lift Range Sustainment (SLRS) contractors ITT and Lockheed Martin. This modernization effort could be improved by the availability of an advanced and fully integrated maintenance, fault isolation and standardization program that addresses interfaces between the two range organizational-level sustainment operations. AFSPC/LG has directed that legacy and future space systems use a standard USAF two-level maintenance concept using 5-level technicians. Further, these technicians are to use standard USAF technical orders, not drawings, in performing maintenance on AFSPC systems. This is <u>not</u> presently the case on the space launch ranges.

The objective of this study concept is to enhance the ability of the AFSPC maintenance organizations to assess the status of, and accurately diagnose (down to one or two LRU's); rectify faults of launch range equipment in timely, cost effective manner; and to concurrently reduce the need for the current manpower levels, and reduce or eliminate the number of 9-level maintenance technicians required to sustain the AFSPC systems.

NOTE: The reader will notice that this research topic was <u>not</u> included in the list of candidate research items identified in section 6.0. This topic was suggested by a senior logistics officer in the Space Launch Range SPO (AFSMC/CWSL) following his review of the preceding LRAT as being applicable, with some differences, to the situation that exists in sustaining the space launch ranges. Consequently, a description of this deficiency was noted and is included in the report for AFRL/HESS consideration.

Deficiencies

- Inability to accurately and cost effectively diagnose launch range equipment.
- No centralized fault diagnostics and maintenance exist for the range equipment.
- Little tech data exists. Most is depended on vendor technical data and drawings.
- There are no cable drawings; hence, configuration control and troubleshooting of anomalies are totally dependent on the skill of contractor legacy technicians and engineers, and availability/accuracy of unofficial records.
- An expensive pool of contractor expertise is required to maintain range equipment.
- This "pool" of expertise is nearing retirement age.
- No standardized equipment concept currently exists at range sites.

Enabling Technologies

- Advanced user-interface techniques for the assimilation of disparate data.
- Diagnostics software algorithms employing an expert systems approach.
- Knowledge Management.
- Standardized logistics and configuration approaches.

Scope of Research

Evaluate the feasibility and requirements for implementing a maintenance and configuration system that will enable Air Force launch organizations to remotely monitor the health and status of launch range equipment, and utility of an advanced diagnostic capability to improve maintainability and readiness of space launch range systems.

Research Tasks

- Review existing diagnostic methods used by launch radar sites and related range equipment.
- Assess government and contractor aircraft and radar diagnostics systems for relevant diagnostics methodologies.
- Identify key data and technologies required assessing and monitoring the health of disparate range site equipment.
- Explore the use of emerging technologies, such as expert systems, to aid in rapid assessment and diagnosis of range equipment anomalies.
- Conduct a knowledge engineering analysis to capture and model the required heuristics and inference rules; input requirements; and outputs for the ALRMS.
- Develop a project plan for the development and implementation of the ALRMS.
- Develop a knowledge management capability to allow the AFSPC to upgrade the diagnostics capabilities as equipment is added, upgraded, or removed from the inventory.
- Develop and demonstrate ALRMS at an operational location.
- Transition the Software to AFSPC and East and West space launch ranges.

Research Products

- Technical Reports documenting the ALRMS design (high level and detailed); development, testing, and transition requirements set.
- Prototype ALRMS demonstration software (software to aid prioritization of standardization, fault isolation, and maintenance strategies).

Potential Benefits

- Enhance the ability of the Air Force to assess the status of, accurately diagnose (to the LRU level) and rectify faults of the space launch range equipment in timely, cost effective manner.
- Long-term goal is to provide methods to aid in standardization of equipment, routines, operations and maintenance.
- Reduce the total sustainment manpower requirements, specifically the need for 9-level technicians on the space launch range sites.
- Allow more centralized fault detection, isolation, and efficient, timely corrective maintenance at all range sites.

Potential Barriers/Risks

- Proprietary systems currently used by launch vehicle developing contractors.
- Reluctance of experts to share their knowledge.

Potential Users

Transition Agent: HQ AFSPC, AFSMC/CL

End Users: AFSMC Launch Vehicle and Spacecraft SPOs, Space Launch Range SPO, HQ AFSPC, and AFSMC Det 8 &9

Estimated Timeframe

The initial conceptual and planning effort could be completed within a twelve-month period. Knowledge engineering and software development, testing and transition would be accomplished over a three-year period.

Estimated Cost

R& D Cost

- Conceptual Design and Planning: \$300-\$500K (depending on the availability of contractor diagnostic software). This effort will also provide the refined concept(s) and plan.
- Software Development and Testing: \$3M.

Transition Cost

- Any modification to government and/or contractor equipment that may be necessary to achieve the concept objective is estimated at less than \$1 million per range. However, it is expected that the study will identify many items of diagnostic equipment already in place at the range meeting the sustainment requirements. This could result in a reduction in the number and types of equipment sets to be acquired.

- Implementation of new software and procedural changes at each range is estimated at $3-$4M/range.

Yearly Maintenance Cost

Some minimum costs could be associated with performing updates to ranges due to new or changes in legacy launch vehicle checkout procedures or processes and equipment that could impact the diagnostic routines in this tool. Additionally, the introduction of a new launch vehicle (EELV) and associated checkout procedures/processes/equipment could also impact annual maintenance costs.

Return on Investment

- Reduced diagnosis time and decision making level requirements to identify faulty equipment (Value TBD).
- Reduced launch inspection complexity, and corresponding launch support manpower and skill levels (Value TBD).
- Significant reduction in number of 9-level technician requirements down to 5-skill level. Cost savings could conceivably equate to savings of up to $1,875,0800.
  ($75K/year per technician X 25 years X a minimum of 100 9-level technician positions on the ranges).
- Total return on the investments shown above (R&D and Transition costs) can be achieved during the first year following IOC of the ALRMS system, and corresponding reduction of contractor personnel described above.

Priority 5. Ground Support Logistics Architecture

Objective
Develop an approach and plan for the sustainment of multi-element space, air, and ground systems within the AFMC support system infrastructure. This approach should recognize and accommodate any unique needs of space systems sustainment and utilize the standard Air Force base and depot level support infrastructure wherever practical.

Deficiencies
Military space systems currently deployed and under development (SBL, SBIRS-Low and GPS III), are made up of constellations of both large and small satellites. Several ground and air-based systems comprise the ground and user segments of the legacy space systems currently performing the command, control and user functions of these space systems. Sustainment of the current systems is typically structured around providing support to individual space systems in a "stovepipe" fashion. The ability to achieve cost savings through the application of commonality of resources is not being fully employed to achieve maximum potential cost savings.

Cited by the Air Force Space Technology Guide, DoD, 2000

Enabling Technologies
This study concept is basically a management and planning project that should identify technology enhancement requirements for the sustainment of common systems, subsystems, and components.

Research Tasks
- Form an IPT comprised of representatives from AFMC ALC's, AFSMC SPO's, and AFSPC sustainment organizations to address the life cycle sustainment needs of both current and future space systems C3I.
- Integrate the sustainment requirements across each individual "stovepipe" program plans for all AFSPC space systems.
- Drive out common support requirements that could be incorporated in a truly integrated space, air, and ground C3I logistics infrastructure.
- Develop an Air Force-wide sustainment model for C3I systems that could potentially identify common support requirements that exist for similar command, control, and user systems, subsystems, and/or key components.

Research Products
This is principally a data collection and analysis research project similar in scope to the priority 6 and 7 research projects identified by this study. The research will require participation in an IPT staffed by AFSMC and AFSPC, with visits to selected AFSPC operational locations to conduct inventories of C3I systems, and interview operators, engineers, and technicians who perform operations and maintenance tasks on the C3I systems, equipment and software.

The effort could result in a degree of equipment standardization that is not present at this time, benefiting both acquisition and sustainment logistics activities. Use of common equipment will favorably impact overall operations and maintenance costs for sustaining AFSPC C3I systems.

At the completion of the study project, a C3I commonality assessment report will be published with recommendations for AFSPC for ways to improve the management and sustainment of the common C3I mission, support, and test equipment identified by the review.

Potential Benefits
By identifying and integrating these requirements, the Air Force could realize significant cost savings in reducing spares inventories and reductions in stock level replenishment quantities, while concurrently increasing the effectiveness of AFSPC's space systems sustainment activities. The increased efficiency and cost effectiveness in providing spares support for space systems may also benefit and reduce sustainment cost for air, and ground C3I sustainment.

Potential Barriers/Risks
There are no known technical barriers or development risks to this project.

Potential Users
Transition Agent: AFSPC and other government agencies that use the launch sites are in the best position to accomplish this task because of their familiarity with the functions, equipment, and current issues/problems associated with launch activities.

Estimated Timeframe
Perform annual assessment in support of the Air Force POM planning cycles.

Estimated Cost
Less than $150k /year to support continuing IPT activity.

Priority 6. Standardized Propellant Carts

Objective

The objective of this concept is to explore and define technical approaches to standardize propellant storage; handling and transfer at government space launch sites. Development and fielding of a common family of launch vehicles under the EELV program, coupled with increasing use of contractor provided launch services offers an opportunity for the Air Force to standardize approaches, processes, and equipment to achieve increased efficiency in launch preparation and operations. Standardized interfaces with future spacecraft and launch vehicles, whether government or contractor provided will significantly reduce development and support costs currently incurred at the launch sites.

Deficiencies

Multiple approaches and a variety of equipment are currently used for propellant loading of spacecraft and launch vehicles at each space launch facility located at VAFB and CCAFS.

Cited by: bd Systems, AFSMC, Det 9 VAFB

Enabling Technologies

Techniques and technologies to enable hazardous fluid transfer and coupling procedures performed at space launch sites.

Scope of Research

Establish an approach for standardizing propellant carts to include the following considerations:

- Improve safety and transfer for all launch vehicle stages.
- Addresses the full range of propellants, gasses, and fluids currently required and used for space systems.
- Provide standard Interfaces. If none exist, define requirements to develop the interface for this application as the de facto standard.
- Resulting propellant cart design(s) must meet technical and safety (OSHA, ICC, NTSB and other Certifications) requirements for use on both government and commercially operated space launch ranges.

Research Tasks

- Research the current handling, storage and transfer techniques used by Air Force and commercial launch organizations for each type of propellant, gases and other fluids at space launch ranges world-wide.
- Identify propellants, gasses, and fluids requirements and characteristics for future space systems.
- Identify high payoff and long lead propellants, gasses, and fluids transfer technologies that would meet future space systems technical and safety requirements and constraints.

- Postulate implementation concepts for propellant, gas, and fluid transfer methods that would enhance sustainment of future space systems.

Research Products

- Recommended standard interface methods for each type of propellants, gasses, and fluids.
- Improved transfer techniques for these propellants, gasses, and fluids.
- Document a concept for a standardized propellant, gas, and fluid cart.
- A comprehensive report describing approaches and technologies needed to standardize approaches for propellant, gas, and fluid handling, storage and transfer for military space ranges.

Potential Benefits

Standardized service equipment at each space launch facility will reduce life cycle sustainment costs. A common family of propellant, gas, and fluid transfer equipment will reduce reparable and consumable spares inventories throughout the sustainment pipeline.

Potential Users

Transition Agent: Development sponsored by AFSMC EELV and Launch SPO, and implemented by AFSMC Det 8 &9

End Users: AFSMC, Det 8 & 9 sustainment organizations

Implementation Schedule

Research two months.
Concept development 6 months.
Summary report 2 months.

Estimated Cost

R&D Cost
$150 K (Includes travel)

Transition Cost
Development of a specific cart for each propellant, gas, and fluid type that is required. Most carts will use similar technologies for each specific class of propellant:

1. Ambient temperature and pressure carts are estimated at $100-$150K range.
2. Cryogenic propellant carts are estimated at $1-$1.5 million to build and certify.
3. High Pressure Carts are estimated at $750-$850K to build and certify.

Yearly Maintenance Cost
This cost will be for replacing limited life items, and corrosion control and re-certification comparable to current systems.

Priority 7. Acquisition and Sustainment Space Logistics Commonality

Objective

The objective of this AFRL Research Project is to assess and identify the commonality of equipment, software, procedures, and training employed during payload-launch vehicle integration and launch site processing. In addition, the study team was advised that the current range modernization sustainment effort would not fully address this problem for the Air Force space lift ranges (SLR). It is determined that common resources at both launch and space lift range facilities could be allocated to support more than one type of launch vehicle and mission, thus reducing the traditional, and costly, "logistics tail" associated with space launch activities.

Deficiencies

A significant number of contacts interviewed by the study team indicated that a major recurring problem at the launch and range sites was the plethora of test and support equipment that performs essentially the same function. This situation of excess test and support equipment assets complicates training of the launch and range support teams, inventory management of launch and range support equipment, and the logistic support necessary to sustain each piece of test and support equipment used.

Presently, the space lift ranges accomplish individual, (and uncontrolled) upgrades to the system – the result is a significant growth in stock-listed equipment from an original 18,000 line item inventory to a present 28,000 line item count. This is more than an F-16 fighter! More items in the inventory means significantly increased Air Force logistics costs. Each additional line item is one more item that must be included under configuration controls, including maintenance and updates to technical data, maintenance cards, support equipment, spares, training etc. A commonality study of the SLR is badly needed because the SLR Sustainment (SLRS) contractor is not tasked to assess how the Air Force got into this situation, only to prioritize the most needed projects.

Each space system and designated launch pad located at Vandenberg AFB and Cape Canaveral AFB launch sites, and CONUS and overseas range sites have their own dedicated set of aerospace ground support equipment. Cost savings can be realized by the Air Force if combining like requirements into a standard set of equipment common to all or most launch processing and range operations. This would standardize test and support equipment used at both east and west launch facilities, and the range sites located in CONUS and overseas.

Reducing duplicate items and standardizing interfaces will become increasingly important as contractor provided launch and range sustainment services for AFSPC, DoD, and other U.S. government (and commercial) launches continue to increase. The Air Force will always be expected to provide some services and utilities for launch pads that are located on government property. Definitive lines must be established and agreed upon to distinguish between launch vehicle, payload, government and contractor

provided services and equipment. Efficient operations, cost reductions and simplified contract management can be realized if common items are minimized, and it is clear which agency will supply the required services.

Cited by: bd Systems, Det 9, VAFB
Space Launch Range SPO (SMC/CWSL)

Enabling Technologies
Many items of test and support equipment used at the Air Force launch and range sites are not current with state-of-the-art electronics, automation and mechanical systems. There are many new improved technologies that could be applied to reduce sustainment workload for launch and range site personnel.

- Data processing and recording technologies could be employed in determining the degree of commonality between equipment and procedures.
- Computer processing, databases, sorting and grading techniques, and categorizing skills could be employed.
- Time phased plots of equipment utilization and crew procedures maturity will also be useful in analyzing final results and drawing conclusions as to defining equipment that is common to launch site processing and specifying specific procedures that should be emphasized in launch site crew training.
- There is very strong potential for application of emerging technologies to develop a common set of equipment for future launch and range operations.

Scope of Research
Perform an assessment of the degree of commonality and technical/performance differences for all equipment and procedures employed on various Air Force launch and range sites during on pad final integration, launch processing, and during launch and orbital insertion monitored by the space launch range sites.

Research Tasks
a. Inventory and generate a list of major equipment and principal procedures employed at VAFB and CCAFB launch site facilities, and at each space launch range site designated by AFSPC.
b. Identify the specific performance capabilities and technical parameters of the equipment identified by the inventory.
c. Assess and define the total equipment set and functions required to support all forecasted launch requirements by launch vehicle.
d. Perform an analysis to identify equipment and procedures that are common to two or more Air Force space system launch requirements.
e. Correlate the equipment set requirements in (c) with current equipment and capabilities in (a), (b), and (c) to identify redundant and duplicative equipment and corresponding processes.
f. Prepare a report citing the requirements and current inventory findings with recommendations to eliminate/replace/retain (in special cases--see below) excess or redundant equipment, with corresponding cost impacts.

It should be noted that there are technical performance nuances in equipment used on different programs that will require careful definitive analysis of the requirements to assure that no program looses a critical capability important for successful launches. The study team noted just such a case at the 50th Space Wing where application of a specific capability of a signal generator was used in a manner that no other AF organizations employed. When the specific piece of test equipment was to be eliminated from the inventory, it created a critical fault detection/isolation problem for the DMSP maintainers since the replacement signal generator did not possess the particularly unique technical capability of its predecessor.

Future programs that will be deployed over the next 10-15 years, such as the Space Based Laser, Microsats, Space Based Infrared System-Low, and the Global Positioning System III, must also be included in the study assessment of launch site test and support equipment requirements.

Some of the key considerations to be included in the commonality assessment include:

- Identify standard interfaces equipment for mechanical, electrical, fluid, optical, thermal and data communication.
- Identify modularity in existing or commercial equipment so that it can be considered as part of the sustainment inventory. These include data packs, batteries, power supplies, fluid transfer devices, special carts, and unique support equipment.
- Review and recommend enhancements to system safety practices and policies that impact the overall safety of a procedure.
- Identify existing training program deficiencies to increase organization efficiency and mission effectiveness.
- Examine integration and launch timelines and sequences for common protocols, hardware and software applications.
- Define requirements for launch site clean up after damage assessments that follow a launch.

Research Products
This is principally a data collection and analysis research project. This commonality assessment will require visits to Air Force launch sites and selected space launch range sites to conduct interviews with engineers and technicians who use the equipment or are participants in the launch and/or range site processing tasks.

The effort could result in a degree of equipment standardization that is not present at this time, benefiting both acquisition and sustainment logistics activities. Use of common equipment will favorably impact overall launch operations costs. Specific areas of commonality to be considered, as a minimum, include: test, integration, refueling, training, purchasing, clean up of hazardous materials following launch.

At the completion of the study project, a commonality assessment report will be published with recommendations for AFSPC for ways to improve the management and sustainment of the common launch and range sites support and test equipment identified by the review.

Potential Benefits
The updating of government launch and range site equipment will need to be accomplished for the new era of contractor provided launch and range support services for both ELVs and RLVs. Concurrent updating of the government launch and range equipment with state-of-the-art and emerging technologies will simplify support processes, and reduce sustainment costs.

Potential Barriers/Risks
There are no known technical barriers or development risks to this project.

Potential Users

Transition Agent:	AFSPC and other government agencies that use the launch and range sites are in the best position to accomplish this task because of their familiarity with the functions, equipment, and current issues/problems associated with launch activities.
End Users:	Launch and range site operators, including contractors, who will use GFE to reduce cost and increase the effectiveness of launch and range site tasks.

Estimated Timeframe
One-year for assessment and planning for common equipment acquisitions.

Estimated Cost

R&D Cost	\$300K (travel is TBD)
Transition Cost	\$350K to \$450K
Yearly Maintenance Cost	TBD

Priority 8. ECU Core Module

Objective

Ground terminals used by current space systems users are provided in a range of sizes, capabilities and capacities. These systems usually configured in racks of electronic equipment generate considerable heat in relatively confined spaces located in mobile vans or other vehicles, aircraft, or ship compartments. One universal need of each employment mode is to control the temperature and environment within these terminals so that the equipment and the personnel can operate effectively, reliably and continuously in all operational scenarios.

The objective of this project is to develop a common ECU Core Module that is highly efficient, scaleable in application, is easily maintainable, and employs environmentally acceptable refrigerants.

Deficiencies

The space user terminals currently deployed in the field come from many manufacturing sources, and are of differing ages and states of the art. The ECUs are considered a relatively major maintenance item since duty cycles for ECU's are as high as any other equipment installed within the terminals. The proliferation of ECU's of many types, sizes, and capacities create a need for substantial logistics investments to sustain the huge variety of terminals in the DoD inventory. ECU's are commonly grouped with other organizational level equipment that receive replenishment spares and piece part support from the standard USAF maintenance and supply systems. The investment to provide this level of inventory to support all the ECU's in the operational inventory goes well beyond anything found in the civilian marketplace.

With the currently imposed environmental regulations to eliminate use of certain fluorocarbon refrigerants that could harm the ozone layer, a technology development effort applied now could afford the Air Force an opportunity to develop a standard ECU module that could be incorporated in the design of all ECU's used in space systems user terminals. This action will greatly simplify sustainment requirements, and will contribute to a significant reduction in ECU maintenance costs.

Cited by: AFSPC DMSP Det 11

Enabling Technologies

Environmentally acceptable refrigerants for high power systems.
Passive or thermionic cooling for lower power systems (Refrigerant-less).

Scope of Research

- Determine the design requirements and attributes for a standard module or family of modules.
- Research the state of the art technologies and refrigerants for ECU usage.

- Determine the applicable range of environmental control requirements for both fixed and mobile systems.
- Develop alternative scaling approaches for adjusting environmental control capability up or down.
- Develop approaches for solid-state controls that can be line replaceable units (LRUs) and have built in fault isolation & test.

Research Tasks

- Determine the state of the art for ECU technology within the industry.
- Select an approach using emerging technologies for: refrigerants, modularity for maintenance, including fault detection and isolation that can be sustained for an extended period beyond current maintenance methods.
- Perform environmental impact analysis.
- Perform cost of ownership analysis.
- Develop an implementation plan.
- Develop and test prototypical equipment concepts ruggedized for military utility.

Research Products

- Adaptable ECU Core Module concepts that are highly supportable and environmentally acceptable.
- A laboratory model of candidate ECU Core Module and Control System that can be used for testing basic performance, scalability, and maintainability.
- A design and prototype of a fully "ruggedized" ECU Core Module concept for current and future space user terminal systems.

Potential Benefits

- A standard ECU module will simplify logistics support and costs by decreasing the population of multiple types of units.
- Modularization should consider separating the coolant loop from the electrical elements thus making each a field level LRU. In this manner, ECU LRU's entering the maintenance stream will be limited to truly inoperable equipment.
- Compliance with U.S. environmental regulations.
- Reductions in personnel, training, and tech data costs.

Potential Barriers/Risks

There are few barriers anticipated to this effort since it is intended to enhance the current and emerging state of the art to Air Force ECU systems, and render them environmentally acceptable. Development risks are also considered equally low.

Potential Users

Transition Agent: The Air Force Air Logistics Center that is responsible for this commodity could monitor the implementation of this development.

End Users: AFSPC maintenance units, and the maintenance units of other military services/agencies that comprise the user segments employing fixed and mobile ECU's.

Estimated Timeframe

Twenty-four months; one year for design and one year for development and testing.

Estimated Cost

R&D Cost

$500K for design and $750K for prototype with testing.

Transition Cost

Introducing new ECU units into the field are most effectively accomplished in an evolutionary manner to avoid cost. The most reasonable method is to incorporate the new units in new terminal systems and replace existing units by attrition.

Yearly Maintenance Cost

These costs should experience a noticeable reduction following the introduction of the new units.

Priority 9. On-Board Data Recorder/Telemetry Package

Objective
Provide the government with basic performance and payload environment data on space launches provided by commercial launch service contractors. Data required during the critical launch period to confirm contract performance of quality assurance, reliability assurance purposes, and to ensure compliance with future Federal Aviation Agency (FAA) rules.

Deficiencies
Inadequacy of government access to critical information to assess and confirm the performance of commercially provided ELV and eventually RLV launch services for administration of performance based contracting.

Cited by: SMC/CLV Det 9, VAFB
Required by: FAA Proposed - Licensing to Operate Expendable Launch Vehicles – Internet Docket # FAA-2000-9753

Enabling Technologies
Non-invasive data mining equipment and software.
Automated Data analysis and reduction software for non-invasive information collection, compaction, transmission, acquisition and reduction.

Scope of Research
With the implementation of total commercially provided launch services for both expendable and reusable launch vehicles, performance and environmental data, that was previously a standard requirement on government and engineering space launches, is no longer available to government launch organizations or contract administrators.

Should an anomaly occur, an "on-board" supplementary telemetry system can aid in determining what went wrong and the cause. If the launch proceeds nominally and the desired orbit is achieved there may still be residual environmental issues that could have a negative impact on the payload. This device would perform the same function as an aircraft flight data recorder but would be designed and/or tailored for use on space launch vehicles.

Traditionally post-flight telemetry data analysis has been a labor-intensive operation focused on the space launch vehicle. A supplemental instrumentation system that can be used for any launch vehicle could also be focused on monitoring the payload to ensure contractual (and safety) flight performance and environmental guarantees are achieved. This is a vitally important issue for commercial launch services where the payload provider is excluded from the launch preparation activities, and final payment for services is based on performance of the launch vehicle and payload. Advanced technologies that could be employed include expert systems and artificial intelligence.

This would contribute to removing as much subjectivity from the flight evaluation process as possible for performance based contracting.

While the function of a system as described in this paper for space applications might seem analogous to aircraft operations, there are significant differences. Data that is monitored and recorded is different for contractual performance metrics, and will be aimed at ensuring that the payload environment did not exceed certain limits as defined in the contract. For expendable launch vehicles, it is not feasible to recover a "Black Box" once the expended launch vehicle has returned to earth; therefore, the data and other critical information must be collected and delivered by a supplemental telemetry transmission as most launch operations end in the destruction of the launch vehicle.

Research Tasks

- Using Failure Modes and Effects Analyses (FMEA) identify and characterize the data needed to assess anomalous situations that could occur during space launches.
- Develop and/or assess methods of extracting data from a launch vehicle and payload telemetry system that can be recorded or sampled by a supplementary telemetry system.
- Explore the use of aircraft flight data recorder technology and hardware that may have application to capture, record, and transmit launch vehicle and/or payload performance.
- Use the AFRL/HESS developed Automated Tech Order generation system for the procedures used on the demonstration flights.

Following the demonstration period, it is conceivable that the prototype hardware could be flown on an actual launch, perhaps as a "Getaway Special Payload" on the NASA Space Shuttle launch.

Research Products

Design requirements and prototype of an independent and supplemental data gathering system for space vehicles that can be appended to launch vehicles or payloads to monitor and aid in the determination that performance specifications have been met.

- A design concept for an enhanced data acquisition system for launch vehicles.
- A laboratory prototype model of the launch vehicle data system.

Potential Benefits

- Provide improved data and information for post flight analysis, and contract performance evaluations.
- May have application for complying with FAA Proposed Rule - Licensing to Operate Expendable Launch Vehicles – Internet Docket # FAA-2000-9753.

Potential Barriers/Risks

While there may be reluctance by providers of launch services to have an item such as this on their vehicle, in researching this project a company that is intending to provide commercial launch services with reusable launch vehicles was asked what they thought of this concept. They thought the idea was of interest and had no issue with including one on their launches.

There are no development risks foreseen for this project.

Potential Users

Transition Agent: AFSMC Launch SPOs in cooperation with the FAA are the most logical agencies to bring this capability to fruition.

End Users: All Launch vehicle operators (Government and Commercial).

Estimated Timeframe

One year for the design and development of the prototype and six months to validate software, then test and demonstrate the equipment to the Air Force acquisition and development organizations making sure human effectiveness parameters are correct.

Estimated Cost

R&D Cost

$750K for development and $250K for demonstrations

Transition Cost

TBD

Yearly Maintenance Cost

Expendable on ELVs, Re-certification for RLVs

Priority 10. Post Launch Pad Damage Assessment

Objective
Develop enhanced methods to evaluate the true operational condition of equipment and support equipment used at launch pads following launches. The means of condition evaluation must go beyond physical inspection and functional testing.

Deficiencies
Inabilities to determine, with confidence, the post launch functionality and operational condition of a launch pad to support and sustain rapid turnaround using on-condition refurbishment techniques.

Enabling Technologies
AFRL developed Aircraft Battle Damage Assessment (ABDA) type technologies (smart skins, assessment software) optimized for launch pad applications.

Cited by: Det 9, SMC/ELV

Scope of Research
The extremely high explosive and acoustic forces associated with launch vehicle liftoff subjects the launch pad, support equipment, and surrounding facility areas to extremely destructive forces. The energy involved, and in some cases corrosive nature of the propellants and other effluents, cause substantial damage that must be repaired before the next launch is possible.
Many pre-launch activities also take place on the pad facility, so the timeline to refurbish a launch facility can be critical to the Air Force's readiness to support space activities, especially during periods of rapid turnaround. AFSMC Det 9 inter-launch refurbishment activities could be optimized if the actual condition of the launch emplacement could be measured in a time efficient manner.

Visual inspections and electrical checks can ascertain some of the refurbishment activities, but the mechanical integrity of structural components must be verified at times from deep within each element. Disassembly and traditional non-destructive testing techniques are sometimes used but they inject added effort to the turnaround activities and can extend the time that launch pads are unavailable to perform typical pre-launch activities. With the consolidation of launch sites and the shift to contractor provided launch services, the government's role in performing their areas of responsibility for future launch efforts is changing. Man-hours and resources expended during the pad turnaround must be minimized whether the contractors or the government does the work. Since launch emplacements take a terrible beating during launches and the refurbishment activities consume a considerable portion of the turnaround effort and cost, one means to minimize the turnaround effort is to accurately assess the pad condition and refurbish only those elements that really need it to ensure that safety requirements are complied with for all launches.

Research Tasks

- Assess launch pad damage history for application of AFRL developed aircraft battle damage assessment (ABDA) technologies.
- Demonstrate that the evaluation of structural and hardstand elements of the launch pad helps reduce extraneous refurbishment effort during pad turnaround.
- Develop a concept that uses "Smart Skin" and the associated assessment programs to accurately assess equipment condition.
- Develop an "on condition" refurbishment program, to minimize turnaround time while maintaining adequate mission assurance levels.

Research Products

- Smart Skin technology applications to launch site equipment.
- Transition ABDA software to evaluate launch site equipment.

Potential Benefits

Reductions in sustainment costs for launch emplacements for both government and commercial operations.

- Replace only required hardware.
- Minimize manpower expenditures.
- Utilize on condition maintenance program with high confidence.

Also applicable to contractor operated launches to enable assessment of commercial launch providers contract compliance for government funded services.

Potential Barriers /Risks

- There should be no barriers to this effort as the need and the cost to benefit ratio is high.
- Technical risks are reasonable since this technology has been demonstrated on other applications (aircraft) and should transition readily to this application.

Potential Users

Transition Agent: SMC Launch SPO sponsor; AFSMC Det 8 &9 implement

End Users: Det 8 & 9 launch site sustainment organization.

Estimated Timeframe

Two years

Estimated Cost

R&D Cost
$ 1 million over two years
Transition Cost
TBD will be a multi-year effort
Yearly Maintenance Cost
An on-condition maintenance program is estimated to provide a cost avoidance savings of 40% of the pad turnaround cost.

Priority 11. SBIRS-Low Crew Simulator System

Objective

Develop an improved crew console Flight Training Device (FTD) for the Space Based Infrared System - Low. This crew simulator should include up to six operator stations to provide simultaneous crew task training for SBIRS - Low space system operations. Conceivably, the SBIRS-Low crew task trainer could be designed for flexibility to provide crew training for several other Air Force space programs such as the Space Based Laser and Global Positioning System III, where coordinated, precise placement of satellites in their constellations will be a key feature of their operational concept.

Deficiencies

A requirement exists for a multi-position, operations crew task trainer for the SIBRS-Low space program.

Cited by: Logistics Director, SBIRS/DSP Program Office, AFSMC

Enabling Technologies

Emerging task simulator technologies under development by AFRL/HE, such as: Virtual Displays, Holography. Incorporate technologies to optimize standardization and commonality of console design, including crew procedures and tasks applicable to operational consoles of legacy and future space systems operations crews.

Scope of Research

There study provides an excellent opportunity to change the paradigm of how space operations crews handle the data that flows to and from spacecraft when the satellite is controlled by crewmembers. The application of new technologies and Human Engineering/Effectiveness techniques and methods to spacecraft control consoles eliminates much of the manually performed analysis and human interpretation that has been done on previous programs. Updates to crew training techniques could be incorporated, so that human operators can still operate and control spacecraft when the higher levels of automation fail or degrade. Crew task trainers that assist students quickly and accurately develop interpretation skills of graphically portrayed situations in lieu of tabular depicted operational scenarios could be prototyped and tested. Human performance studies should also be performed to assess crew performance during these degraded operational states to assure that the readiness levels can be maintained by these means before applying the techniques to controlling operational satellites.

Research Tasks

- Review crew operational procedures for the SBIRS-Low spacecraft.
- Perform a Training System Requirements Analysis (TSRA).
    - Define and derive a set of functional requirements for the crew task simulator.
    - Decompose functional requirements to discrete tasks to be performed by each crewmember.

• Develop a crew simulator design specification.

The research would be accomplished by review of SBIRS-Low contractor's documentation; discussions with and training plans provided by the SBIRS-Low SPO, and the AFSPC training organization. Inclusion of SBL and GPS-III training requirements could be added in the out years as a growth item.

Use lessons learned from the Air Force MILSATCOM training program, and aircraft simulators, to devise a design strategy. Develop a SBIRS-Low laboratory working engineering model for testing by AFSPC crewmembers. Refinements will be incorporated based upon testing, and will be included in a full-scale first article data console crew task simulator.

Research Products

1. Crew trainer Design Specification using advanced simulation techniques, including virtual linkup, and incorporating human factors techniques and methods.
2. The identification of the enabling technology developments necessary to produce the laboratory model.

Potential Barriers/ Risks

This crew trainer should be developed by the SBIRS SPO as part of the project development and deployment with technology and HE inputs from AFRL.
Development risks are considered minimal.

Potential Users

Transition Agent: SBIRS Program Office

End Users: AFSPC

Estimated Timeframe

Phase I: Three to four months for data collection, analysis, and generating requirements followed by 8 to 9 months of simulation design resulting in a Critical Design Review (CDR) with an engineering model in 18 months.

Phase II: Full scale, first article crew simulator – 9 months.

Phase III: Adopt and incorporate standardized/commonality features applicable to other Air Force satellite programs – 12 months.

Estimated Cost

R&D Cost	\$1.5 to \$2.0 Million dollars for Phase I
Transition Cost	Production and installation \$5-7 Million
Yearly Maintenance Cost	TBD

Priority 12. Optics Decontamination Prior to Launch and Following Payload Integration

Objective
Removing the optics or mirrors from a spacecraft at the launch site for cleaning due to contamination is not always a feasible option due to the time required for such maintenance actions, and the need for realignment of the optics following the cleaning function. The objective of this study concept is to identify a cost effective and efficient mechanical, chemical, or electrical device or technique of cleaning and/or decontaminating spacecraft payload optical surfaces at the launch site.

Deficiencies
Keeping payload optics clean and contamination free during launch processing is a known, recurring problem at the launch site during integration and checkout of sensor spacecraft. Contamination can come from environmental conditions as well as from man induced activities. At the present time there are no quick and efficient methods or processes to perform optics decontamination tasks on the launch pad. Sensitive spacecraft optical surfaces are usually cleaned, calibrated, aligned and protected/covered (large plastic bags) at the spacecraft developing contractor's facilities prior to shipment to the launch site. The contamination problem typically occurs at the launch site as the spacecraft is mated to the launch vehicle, then run through final launch readiness testing.

Cited in: DoD Space Technology Guide, 2000; and SMC Det 9, VAFB

Enabling Technologies
Cleaning technologies (Plasma, Electrostatic Discharge, Alpha Bombardment); Robotic manipulators.

Scope of Research
Air Force spacecraft performing intelligence, surveillance, and reconnaissance (ISR) missions usually have a considerable area of critical optical surfaces that must remain free of contamination as the spacecraft goes through integration, test, and launch site processing. The optics on these spacecraft are large, lightweight, and deployable. Others may be modular, part of space-based laser/lidar remote optical sensing systems, and a few may be space-based relay mirrors with optically efficient coatings.

The scope of this study concept is to identify specific mission spacecraft that may require special protection and optics cleaning prior to launch, and define the technical requirements and processes for efficiently accomplishing the optics cleansing without disruption to the launch processing activities, and without damage to the optics lens.

Research Tasks
1. Conduct analysis and trades to determine the best processes and methods for accomplishing optics decontamination at the launch site.

2. Develop design and performance requirements for an optical decontamination device.
3. Conceptualize laboratory tests for scale models for cleaning mirrors or optics using the proposed decontamination techniques and evaluate results.

The primary issue to be addressed in the approach is to accurately determine if and when the payload optics needs to be decontaminated, and then perform this task without optical surface damage. It is postulated that several alternative techniques may be carried to field-testing on full scale, non-flight payload optics before a final approach is selected.

Research Products
1. Concepts for robotic devices, cleansing materials, optics degradation, and identification of the human induced factors that could contribute to decontaminate optics during integration and test at the launch site.
2. Concepts for verification that the decontamination techniques and processes have successfully removed contamination from the optics, and validation that the optical alignments remain accurate.
3. A report with design and performance requirements for an optics decontamination device.

Potential Benefits
Cost and launch preparation time and resources could be reduced during spacecraft payload integration and payload mating to the launch vehicle.

Potential Barriers/ Risks
There are substantial physical and scheduling constraints on technicians that work on preparing space vehicles and payloads on the launch pad.

Technical risk is considered moderate.

Potential Users

Transition Agent:	Launch SPO, Det 8 & 9
End User:	Det 8 & 9

Estimated Timeframe
One to two years.

Estimated Cost

R&D Cost	TBD
Transition Cost	TBD
Yearly Maintenance Costs	TBD

Priority 13. Modeling and Simulation of Launch Vehicle Integration, Test and Launch

Objective
Provide the Air Force (and other government agencies) with a means to evaluate the performance of commercially provided space transportation pre-launch processing to facilitate readiness and contract performance assessments.

Deficiencies
A common concern voiced by personnel at the VAFB launch site and by HQ AFSPC staff was that comprehensive logistics support planning and analysis for sustainment of commercially provided launch services for expendable launch vehicles at both VAFB and CCAFS has not been rigorously accomplished. Concern exists that deficiencies or shortcomings of the commercial sustainment processes and/or resources could jeopardize scheduled launches.

Cited by: SMC/MILSTAR; AFSMC/CL Det 9

Enabling Technologies
Application of real time predictive modeling with rule based expert enhancements.

Scope of Research
Launch processing of EELV launch vehicles is intended to be contractor provided services. There has been little evidence of adequate coordination accomplished with the Air Force host organizations at the launch sites, or the potential payload users to ensure that sustainment provisions will meet requirements. This has also led to growing concern that the product assurance measures normally associated with government operations may be diminished, or lost.

One means to evaluate the thoroughness and efficiencies of the contractor processes is to model the planned integration, test and launch activities to allow AFSPC and other government agencies the ability to perform comprehensive testing of all functional responsibilities <u>before</u> operations are initiated. The performance of various logistics processes and alternatives may be simulated and exercised to ensure that optimum task assignments are made and potential problem areas or bottlenecks identified before they impact launch schedules.

Research Tasks
- Develop the requirements for a family of computer models to simulate pre-launch operations and logistics functions associated with commercially supplied launch services for a variety of legacy and future expendable launch vehicles.
- Establish metrics with which to measure and evaluate detailed contractor plans and schedules for providing launch service operations and functions. The metrics must include means to measure performance against contractual requirements.

- Test the simulation model(s) to validate all launch functions and services can be measured to evaluate progress of contractor in meeting performance requirements in real time.

Research Products

- Technical Reports documenting the model design (high level and detailed); development, testing, and transition requirements.
- Advanced Demonstration A simulation model using project control techniques, including expert systems enhancements, to measure resource allocations and performance in real time.

Potential Benefits

Provide AFSPC and other government agencies with the means to more accurately monitor and control commercially provided launch services.

Potential Barriers/Risks

No technical barriers or risks are associated with this effort. However, there very likely will be management and contractual issue that must be mitigated before implementation.

Potential Users

Transition Agent:	TBD (SMC Launch SPO and other agencies using the EELV family of launch vehicles could share this responsibility.)
End Users:	Virtually every government (and possibly commercial) launch manager would find this tool and technique beneficial.

Estimated Timeframe

One year

Estimated Cost

R&D Cost	$575K (Including Travel)
Transition Cost	(Included as part of R&D cost)
Yearly Maintenance Cost	$50K

Priority 14. Leaks and Hot Spot Detector

Objective
The objective of this research concept is to develop a universal, portable hardware device that quickly detects and isolates fluid leaks and hot spots on space launch vehicles and their payloads during launch processing. Sixteen fluid types that comprise a variety of liquids and gasses that can be used aboard spacecraft were listed in part 2 of the AFRL Space Logistics Requirements Study, dated July 2000. Thus, the Leak and Hot Spot Detector would require the sensor capability to detect a wide range of liquids and gases to ensure launch safety. Early detection of leakage problems directly contribute to launch site safety, and can will help avoid time consuming /costly launch processing delays.

Deficiencies
There is no totally reliable detection device currently available to detect and fault isolate a large variety of leaking fluid (liquid or gas) from launch vehicles and their payloads during integration, test, assembly and checkout activities at Air Force launch sites.

Cited by: SMC/CL, Det 9, VAFB; and the DoD Space Technology Guide, 2000

Enabling Technologies
Several technologies will be assessed and considered in developing a solution for an acceptable leak and hot spot detecting device. These will include, as a minimum, diagnostic systems, robotic systems, non-intrusive inspection techniques, and detector and snifter methods for the liquids and gasses associated with launch sites. Included in this list must be those technologies necessary to ensure safety and other human factors considerations when technicians are in the presence of highly flammable and/or toxic fluids and gases.

Scope of Research
Develop concepts for a low cost, reliable detection device that will assist launch site technicians identify leaks and hot spots in a timely manner incorporating safety and other human factors considerations to accomplish this fault detection, fault isolation task far quicker and more reliable than by the current means of manual and visual inspection.

Research Tasks
1. Examine current leak and hot spot failure modes and evaluate effectiveness of current detection methods and techniques.
2. Develop technical requirements for leak and hot spot detection and fault isolation tasks pertinent to all functions performed during launch site operations.
3. Perform engineering analysis and trade studies to synthesize data collected by (1) and (2), and derive performance requirements for a detection device.
4. Identify and evaluate existing detection technologies for potential application to the requirements in (3).

5. Develop alternative design approaches for a hardware device that incorporates both leak detection and hot spot identification.
6. Include a concept incorporating growth potential for integrating the detection device with a Microsat for performing remote inspection of space-based military assets. It is envisioned that such a Microsat could be launched with a spacecraft, and fly formations with the spacecraft to conduct leak and hot spot evaluations in-situ.

Research Products

1. A report describing design requirements for a detection device to facilitate and expedite safety inspection requirements during space vehicle launch processing, and assure OSS&E requirements associated with launch readiness are achieved.
2. This research concept could be combined with other diagnostic developments under way at the AFRL, or to satisfy another deficiency described in this report, such as the optics decontamination study concept.

Potential Benefits

1. Improved effectiveness of Launch Site Safety.
2. Reduce inspection timelines and workload.
3. Contribute savings in both payload integration launch time by quickly avoiding and/or mitigating safety problems created by leakage and hot spots that occur during the launch countdown.
4. Assure compliance with the Safety requirements of the Air Force OSS&E program.

Potential Barriers/Risks

No known or apparent barriers or technical risks exist.

Potential Users

Launch site integration, test, assembly and checkout, and safety personnel (Military, NASA, and Contractor).

Estimated Timeframe

Twelve months

Estimated Cost

R&D Cost	$500k
Transition Cost	TBD
Yearly Maintenance Cost	Certification TBD

Priority 15. Remote Inspection of Surfaces

Objective
Spacecraft, payloads, and launch vehicles are enclosed with critical surface structure material designed to maintain and provide for the configuration integrity, protection and operation of the spacecraft during assembly and checkout, launch, and orbital insertion. As the satellite's parking orbit is achieved, a method of efficiently transmitting the data with which to determine the spacecraft's condition to the ground operators is needed. This data transmittal should minimally impact the basic spacecraft command and control data systems, if they are shared.

Accessibility to inspect the spacecraft diminishes as the launch processing progresses up to the launch window at the space launch facility. In addition to knowing the status of the satellite and launch vehicle external and internal surfaces following the stresses of launch and orbital insertion is the need to monitor status of the spacecraft surfaces on a periodic basis throughout the pre-launch assembly, integration, and checkout process. This is especially critical should an accidental event or anomaly occur during the launch in order to determine if there has been any distortion or damage to the spacecraft and payload.

The objective of this project is to develop a device that would remotely monitor spacecraft and payload surfaces during the integration, assembly, and test phase, and as vital events occur during the launch and orbital insertion process.

Deficiencies
Inability to detect hidden mechanical or structural failures in spacecraft during the latter phases of launch processing, and following deployment into an operational orbit. Normal, functional, or electrical testing may not be able to verify a spacecraft's structural integrity or the full operational capability of a mechanical system after surface damage has been sustained.

Cited in: Air Force *Space Technology Guide,* DoD, May 2000

Enabling Technologies
Smart Skins; remote-sensing techniques; automated launch site testing and integration techniques; and three-dimensional modeling of the surface under inspection.

Scope of Research
Some materials that are often used as a secondary structure in aircraft, such as honeycomb structures, can also be used as the primary structure for spacecraft. Materials used in spacecraft manufacture are often very similar to those employed on aircraft. In view of this similarity, it is the opinion of the study team that the Aircraft Battle Damage Assessment (ABDA) technologies developed by AFRL for aircraft may also have beneficial application to spacecraft.

Three complementary inspection strategies are suggested for evaluation by AFRL over a two-year research project. They include:
1. Tele-operated, human visual inspection.
2. Automated scanning with human visual inspection.
3. Automated scanning with machine-vision inspection.

Perform a requirements analysis for a spacecraft surface monitoring system to establish the technical sensing requirements and parameters for a sensing and monitoring device. An evaluation of the three strategies in meeting the requirements will drive out the optimum technology to test for application to spacecraft surface monitoring. A follow-on task would be the design, development and production of a laboratory-working model.

The second part of the study project would be the conversion of the working model into a field trial system to develop and test procedures using man-machine simulations. Demonstrations of the surface monitoring device can be accomplished at contractor facilities or at Air Force launch sites.

Research Tasks

- Perform requirements analysis to establish technical sensing requirements and parameters for a spacecraft surface monitoring system.
- Perform trades and analysis between (1) tele-operated, human visual inspection; (2) automated scanning with human visual inspection; and (3) automated scanning with machine-vision inspection to determine the most effective approach to remote surface monitoring/inspection.
- Develop the most promising approach and concept for a laboratory model.
- Demonstrate the prototype to validate application to spacecraft surface monitoring/inspection.

The technology developed by this project could be extrapolated and incorporated with future Microsat operations. A Microsat with adapted sensor technology to perform remote inspection of surfaces could be launched from the ground, or from a space-based platform, to inspect Air Force satellites suspected of incurring surface damage due to natural or enemy actions.

Research Products

A prototype model to test an application on a typical spacecraft to demonstrate accuracy and effectiveness of remotely assessing the mechanical condition of spacecraft surface.

Potential Benefits

- The application of a remote inspection device for spacecraft surfaces to assure flight readiness, and avoid extended launch site downtime to perform visual and manual inspection with associated costs.

- For future on-orbit operations, remote inspections could verify the operational suitability of space system structures to ensure that launch of replacements or on-orbit repair could be scheduled and performed on a verified, on-condition basis.
- Evaluation of the potential application of ABDA technology for spacecraft surface monitor/inspection could determine with higher degree of confidence if a spacecraft, payload, and/or launch vehicle will achieve orbit and function as intended, or if a replacement spacecraft must be launched due to damage sustained by the spacecraft's surface.

Potential Barriers/Risks

There have been similar terrestrial applications so the barriers and risks should be minimal

Potential Users

Transition Agent:	AFSMC Launch SPO, commercial spacecraft developers
End Users:	Air Force and commercial spacecraft operators

Estimated Cost

R&D Cost	$2 million over two years.
Transition Cost	No technique now exists
Yearly Maintenance Cost	TBD

APPENDIX B
DoD Space Technology Guide (STG) Review

DoD SPACE TECHNOLOGY GUIDE (STG) REVIEW

INTRODUCTION

The 4 May 2000 draft document of the DoD Space Technology Guide (STG) was reviewed by the study team for correlation of technology requirements development projects suggested in the document, to candidate logistics research projects derived and identified in the DO 12 AFRL Space Log Front End Analysis Study. When completed, this DoD STG will be issued by the Office of the Secretary of Defense. The document describes the need, i.e., technology "pull" or "demand" to match the technology "rush" or "supply" provided both by U. S. Government agencies and by commercial interests worldwide.

The STG serves as a guide by cataloging a multiplicity of national security space related technology activities needed or under development across the U.S. space community. It also offers department-level guidance with respect to key enabling technologies that must be "done and done right." This includes technologies that may provide major steps forward in their own areas and thereby leverage other areas, such as space logistics, where advances in space capabilities, performance, and operations (ground and space) may evolve. The DoD STG period of interest is for the next twenty years, from 2000 through 2020. It addresses nine mission focused technology areas. They include:

Space Transportation
Satellite Operations
Navigation
Command, Control and Communications
Intelligence, Surveillance, and Reconnaissance
Environmental Monitoring
Space Control
Information Operations
Force Application

APPROACH

This subtask was accomplished by surveying the above 9 mission areas to identify enabling technology content that may have application to space logistics potential technology development projects that may be funded by AFRL/HESS under Program 6.3 (Advanced Technology Development) resources. Program 6.3 seeks to transition emerging technologies to system applications. The STG suggested Space Logistics Technologies, including the writers suggest list of "other space log technologies" for each of the 9 mission areas, are presented with each mission area discussed below, but <u>not</u> in any order of priority in the following sections.

Space Transportation

DESCRIPTION: Space Transportation encompasses the traditional spacelift mission of delivering payloads to orbit, plus emerging missions such as on-orbit refueling, servicing, maintenance, repositioning, and recovery.

OBJECTIVES: Provide routine, assured, low cost, low risk access to space with launch on demand and on-orbit servicing and transfer.

PROJECTED APPLICATIONS: Low cost expendable launch vehicles, reusable launch vehicles, Space Operations Vehicle, Space Maneuvering Vehicle, On-Orbit Servicing Vehicle, and Orbital Express.

STG SPACE LOGISTICS TECHNOLOGIES:

- Autonomous rendezvous and docking systems
- Interface standards
- Two-way fuel transfer systems
- Modular system architectures

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Reconstitute and repair
- Diagnostic systems
- Modeling and simulation
- Payload and launch vehicle integration
- Payload and launch vehicle launch site processing
- Standardization of operations
- Ground based payload and launch vehicle damage assessment
- Human resources
- Common protocols for maintenance and repair
- Human centered automated test bed for check out of new procedures and training
- Advanced ground based cryogenic handling and storage systems
- Encrypted inventory systems
- Man made radiation protection
- Intelligent tutoring

Satellite Operations

DESCRIPTION: Satellite operations (SatOps) are conducted to verify and maintain satellite health; to reconfigure and command payloads, to detect, verify and resolve anomalies; and to perform launch and orbital operations. The three basic functions of SatOps are telemetry monitoring, tracking, and commanding.

OBJECTIVES: Mission area objectives are to provide integrated operation/mission planning, on demand command and control, precision tracking and geolocation of critical space assets, global space traffic control, and on-orbit satellite servicing, both routine and emergency.

PROJECTED APPLICATIONS: Discoverer II, TechSat 21, the Astro vehicle of Orbital Express, Space Based Infrared System, Space Based Laser, Space Based Radar, and the next block upgrade of the Global Positioning System.

STG SPACE LOGISTICS TECHNOLOGIES:

- Robotic, adaptive, self training, human machine interface agents
- Data bases, software, integration, modeling, and processing techniques
- Advanced tools algorithms for modeling and simulation
- Interoperable software, electrical and mechanical interfaces
- Interoperability standards and protocol schemes
- Space-based internet
- Space-based relay for telemetry and command destruction

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Payload and launch vehicle launch site processing
- Modeling and simulation
- Human – computer interfaces
- Standardization of operations
- Automated tech order generation
- Cognitive neural science telerobotics
- On-board diagnostics, detection, and damage assessment systems
- On-board survivability assessment
- Intelligent information systems

Navigation

DESCRIPTION: Space-based navigation systems provide three dimensional position data and a timing standard to military, civil, and commercial users worldwide, 24 hours a day. Precision navigation and timing provide targeting and geolocation information critical to coordinated and accurate force application by any platform in any medium. Today, the GPS provides nearly worldwide coverage and represents a national asset.

OBJECTIVES: Navigation mission area objectives are to provide: continuous global coverage in all environments, continuous coverage of space, improved positional and timing accuracy, denial of unauthorized third party use, and timely warning of bad data or failures.

PROJECTED APPLICATIONS: Advanced GPS inertial navigation technology, new technology space born atomic clocks, military waveform assessments, and future military waveform user equipment with anti-jam capabilities.

STG SPACE LOGISTICS TECHNOLOGIES:

- Improved precision time sources
- Re-programmable radios and other electronic system components
- On-orbit reconfigurability/upgrades to accommodate changing GPS requirements
- Software to provide continuous status reporting

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Payload and launch vehicle launch site processing
- Modeling and simulation
- Human computer interfaces
- Standardization of operations including data fusion and advanced algorithms for processing and exploitation
- Automated tech order generation
- High density interconnected electronics
- On-board diagnostics, detection and damage assessment
- On-board survivability assessment
- Intelligent information systems

Command, Control, and Communications

DESCRIPTION: Command, Control and Communications (C3) are the key to managing the battlespace and exploiting information superiority as enablers of all other operational and support missions. Effective C3 assures situational awareness and provides the ability to control terrestrial, space, and missile forces at all levels of command.

OBJECTIVES: Command and control objectives are to monitor and assess global conditions and events and maintain a common situational picture. Objectives also are to execute military operations, allocate task command and control U.S. space resources; collect, process and fuse data and retrieve and/or distribute information to military personnel. Communications objectives are to provide global, space-based, high-band width, high data rate; robust, secure and seamless communications for national security requirements.

PROJECTED APPLICATIONS: Configurable aerospace command center, global awareness virtual test bed, joint aerospace tasking order, and the global grid advance communications infrastructure.

STG SPACE LOGISTICS TECHNOLOGIES:

- Strategy-to-task software algorithms
- Intelligent network management technologies
- Self-forming, self-healing terrestrial networks
- High volume/speed processing, storage and display technologies
- Advanced waveforms for efficient and assured links

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Modeling and simulation
- Standardization of operations
- High density interconnected electronics
- Cognitive and neural science telerobotics
- On-board diagnostics, detection and damage assessment
- On-board survivability assessment
- Intelligent information systems

Intelligence, Surveillance, and Reconnaissance

DESCRIPTION: ISR permeates almost every area of national security activity, from peace through war. Together with real time communications and information processing, ISR technologies represent the enabler. It

involves primarily electronic systems to find, watch, and collect data from sources and provide as information to users. Its success is through information dominance.

<u>OBJECTIVES:</u> Military objectives are to provide global day/night all weather surveillance and reconnaissance; timely threat warning information; real time detection, I.D. characterization and geolocation of fixed surface/subsurface and mobile targets; provide information on nuclear, biological and chemical weapons and events and provide intelligence tasking, cross cueing, processing and discrimination.

<u>PROJECTED APPLICATIONS:</u> Advanced target detection and imaging from SBIRS (high and low systems), SBR, and SBL; infrastructure platforms and projected information management systems.

<u>STG SPACE LOGISTICS TECHNOLOGIES:</u>

- On-orbit resupply concepts
- Future information architectures
- Information exploitation technologies
- Transition from legacy systems to new ones
- ISR modeling and simulation
- Non-intrusive inspection technology
- Modular optics

<u>OTHER SPACE LOGISTICS TECHNOLOGIES:</u>

- Modeling and simulation
- Payload and launch vehicle integration
- Payload and launch vehicle launch site processing
- Human computer interfaces
- Ground based payload and launch vehicle damage assessment
- Automated tech order generation
- Virtual reality for tech data
- High density interconnected electronics
- Cognitive and neural science telerobotics
- Human resources and factors
- Common protocols for maintenance and repair
- Human centered automated test bed for check out of new procedures and raining
- On-board diagnostics, detection, and damage assessment

- On-orbit survivability assessment
- Advanced ground-based cryogenic handling and storage
- Encrypted inventory systems
- Payload and launch vehicle launch site processing

Environmental Monitoring

DESCRIPTION: Environmental support for land, sea, and air forces include the day-to-day provision of space products and services to the effective operational forces. Environmental monitoring and the development of geospacial information for national security purposes rely on defense, civil, and commercial space capabilities.

OBJECTIVES: Mission areas objectives are: to provide: timely, high quality global weather data to operators, three dimensional characterization of ocean and land topography and the atmosphere; differentiation of object classification/identification and timely change recognition; improved capabilities to model and forecast space environmental parameters; and detect and assess space weather effects.

PROJECTED APPLICATIONS: WindSat program, Communications/Navigation Outage Forecasting System, GEOSAT, Advances Solar Telescope, and Solar Mass Ejection Imager and National Polar-orbiting Operational Environmental Satellite System.

STG SPACE LOGISTICS TECHNOLOGIES:

- Advanced atmospheric characterization, modeling, and processing
- Development and improvement of advanced weather prediction models

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Ground based diagnostics systems
- Payload and launch vehicle integration
- Standardization of operations
- Payload and launch vehicle damage assessment
- Automated tech order generation
- Virtual reality for tech data
- Common protocols for maintenance and repair
- Survivability assessment
- Payload and launch vehicle launch site processing

Space Control

DESCRIPTION: Full control of space requires freedom of operations therein plus the ability to deny others either the use of space for themselves or he ability to degrade ones own space operations.

OBJECTIVES: Space control to provide the capability of space surveillance, protection, prevention, and negation. These objectives are being pursued under technology programs and their testbeds to underwrite the full range of target, performance, and scalability issues that will follow initial test results.

PROJECTED APPLICATIONS: Space Threat Warning and Reporting, Ground-Based Laser, Active Imaging Test Bed Experiments, and Space-based Laser Integrated Flight Experiment.

STG SPACE LOGISTICS TECHNOLOGIES:

- Real time combat damage assessment technologies
- Ability to reconstitute and repair asset systems on orbit
- On-orbit maneuvering, diagnostics, processing and mission management
- On-orbit detection of space environment hazards
- Non-intrusive inspection technology
- Modular optics
- Increased satellite on-board data processing and storage for timely data delivery

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Reconstitute and repair
- Human computer interfaces
- Standardization of operations
- Payload and launch vehicle damage assessment
- Automated tech order generation
- Virtual reality for tech data
- Cognitive and neural science technologies
- On-board survivability assessment

Information Operations

DESCRIPTION: The emerging technical and mission area of Information Operations involves systems and activities to gain, exploit, defend, or attack information and information systems. Information operations are conducted throughout all phases of an operation and across the range of military

operations; its techniques encompass and extend many of the aspects of now traditional electronic warfare.

OBJECTIVES: The objective of information operations is to guarantee data delivery and information exchange to/for users. It involves robust capability scalable to all national security applications across the board, including a set of diagnostic and evaluative tools to determine what happened and how to fix it.

PROJECTED APPLICATIONS: New programs related to information survivability operational sensors, damage assessment, recovery, forensics, and planning awareness for decision support.

STG SPACE LOGISTICS TECHNOLOGIES:

- Automated vulnerability assessment
- Real time detection of external intrusions and internal misuse
- Information fusion with multi-level security
- Increased satellite on-board data processing and storage for timely data delivery
- Integrated situation assessment tools
- Integrated damage assessment tools
- Non-intrusive inspection technology

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Ground based diagnostics systems
- Modeling and simulation
- Virtual reality for tech data
- High density interconnected electronics
- Cognitive and neural science telerobotics
- Survivability assessment
- Intelligent information systems
- Information logistics to support information warfare operations.
  See Joint Vision 2010

Force Application

DESCRIPTION: Force application through or from space is currently limited to nuclear-armed long-range ballistic missiles, short-range theater or tactical ballistic missiles, and C3 services and ISR products of space-based sensors and links.

OBJECTIVES: Mission area objectives relates to deterrence, defensive support and offensive concepts. Deterrence pertains to ballistic missiles; defensive support relates to the development of National Missile Defense forces; offensive concepts pertain to the Space-Based Laser system and other projected space-based offensive concepts.

PROJECTED APPLICATIONS: Conventional ballistic missile technologies and systems and Airborne Moving Target Indication/Ground Moving Target Indication for battlefield strike operations.

STG SPACE LOGISTICS TECHNOLOGIES:

- Enabling technologies for space delivery of conventional systems
- Very high capacity onboard computing

OTHER SPACE LOGISTICS TECHNOLOGIES:

- Modeling and simulation
- Human computer interfaces
- Automated tech order generation
- Human resources and factors
- Encrypted inventory systems
- Intelligent information system
- Man-made radiation protection
- Intelligent tutoring
- Payload and launch vehicle launch site processing

Microsatellite Technology

The Space Technology Guide includes a chapter dedicated to Microsatellite Technology. It was reviewed as part of Task 1 effort because it represents a unique phase of Space Logistics.

The term "Microsatellite," or "Microsat" for short, has become a generic reference for entire new classes of satellites whose size and weight reduction from traditional satellites may be measured in orders of magnitude. Technically, the Microsat specific nomenclature derives from their mass, or weight on earth, as follows:

- Traditional satellites weigh upwards of 1,000 kg, and require medium or large launch vehicles to boost them into orbit
- Smallsats weigh on the order of 500 kg, and are defined as fitting on the smallest launch vehicle (e.g. Taurus)

- Microsats generally range from 100 to 10 kg
- Nanosats range from 10 to 1 kg
- Picosats weigh less than 1 kg

Microsats of appropriate mass, size and capability could:

- Use easier-to-launch smaller satellites to augment existing constellations during contingency or theater operations
- Perform spatial-purpose or limited-scope missions, such as nuclear detonation (NUDET) detection
- Operate as distributed or multifunctional platforms in the performance of several space missions
- Support Space Control concepts
- Provide unique capabilities to enable new, innovative operational concepts, such as:
  - On-orbit maintenance, supply and servicing of operational satellites
  - The use of satellite clusters to provide virtual apertures for sensing operations

MICROSAT APPLICATIONS

Microsat can and are being used for space system demonstration test beds. An example is the AFRL MightySat 1, a 68 Kg satellite launched to LEO as a shuttle hitchhiker experiment to demonstrate advanced sensors, space environment monitoring, and miniaturized satellite subsystems.

Microsats information will checkout integrated GPS communications and ranging, micro-propulsion and minimum fuel formation flying. Also, since multiple micro satellites could replace large monolithic satellites, autonomous control algorithms are being developed to reduce ground control requirements.

Other applications include testing of: proximity operations techniques for on-orbit servicing fail-safe collision avoidance (with man in the loop); on-orbit servicing itself (inspection, supply, repair); low-cost manufacturing; tactical space-based sensing; and low-cost rapid launch capacity.

<u>AFRL EXPERIMENTAL SATELLITE SYSTEM (XSS)</u>:

The XSS program evolved from the joint DoD, DOE, and BMDO activity that produced the Clementine II microsatellite technology program started in FY 1996. XSS is currently a series of flight experiments to demonstrate increasing levels of autonomous on-orbit inspection, docking, and servicing. Key technologies are high-performance propulsion, autonomous proximity algorithms, and next-generation optical sensors. XSS-10, the first in this

series, will launch as a secondary payload on a Delta II in late-2000. It will demonstrate rendezvous, proximity maneuvering, and visual inspection of the Delta upper stage that deployed it. The XSS-11 microsatellite will launch in 2004 and demonstrate docking and servicing in the form of power or fluid transfer to the host vehicle. The XSS-12 microsatellite is scheduled for launch in 2005 and is tentatively planned to intercept a tumbling spacecraft, reorient it, and reposition it to an alternative orbit.

AFRL TECHSAT 21 PROGRAM:

The Air Force Research Laboratory has initiated the TechSat 21 program to develop the technologies needed to enable distributed satellite systems. Sparse aperture sensing was selected as a reference mission to help identify technology requirements and to allow an easy comparison to conventional approaches.

Basic research is being conducted in sparse aperture signal processing, micro-propulsion, formation flying, collaborative control, spatial ionospheric effects, and microelectromechanial systems for spacecraft.

MICROSATELLITE SPACE LOGISTICS TECHNOLOGIES:

The STG did not record specific logistics technologies directed to Microsat. Therefore, the list of technologies cited below is contributed by the bd Systems study team:

- Special case Microsat payload integration to the launch vehicle and launch site processing
- Launch site Microsat/Launch Vehicle pre-launch inspection and processing
- Launch readiness concepts for formation flying
- System architecture to accommodate satellite cluster configurations that can easily be changed to perform a variety of military missions
- New methods of inventory control to cope with launch-on-demand high priority missions
- New ground methods of decontamination of small optics, quick change of damaged structures, and lubrication of critical joints
- Microsats human-computer interfaces
- New techniques for Microsat standardization, automated tech order generation, maintenance protocols, on-board diagnostics and ground-crew training
- Modeling and simulation for Microsat cluster control
- Space-based infrastructure to store, refuel, repair and reconfigure microsats
- Develop scenarios that show economical use of microsats for space logistics missions (Inspection, Resupply, Maintenance and Servicing). This could result in requirements for innovative technology developments for ground and

space-based infrastructure elements that can enable efficient microsat operations.
- Microsat payload preparations and certification techniques

Conclusions

1. Air Force missions in space will continue to evolve over the 2000 through 2020 time period, and logistics operations, processes, and techniques must keep pace.
2. Space logistics technologies suggested in the STG document, and supplemented by the bd study team, could facilitate major steps forward in their own areas and thereby provide leverage to one or more other areas – to the point where revolutionary advances in space capabilities, performance and operations may result.
3. For the long term, the Air Force's pursuit of the several classes of Microsat, from Smallsats down is geared toward the achievement of new capabilities leading to new operational paradigms; i.e., the Microsat "vision' is for combinations of characteristics and capabilities that will enable new "ways of doing business" operationally. New and innovative space logistics systems will be required to support this premise.
4. Approximately 50 technologies were identified in this report as having application to space logistics requirements; however, not all are equal in their importance to AFRL/HESS research goals. Resources and priorities are always considerations. However, it is suggested that the 50 technologies could be distilled down to the following core list of five space logistics technologies presented in no order of priority.

    - **Data Management and Encrypted Information Processing.** Includes: inventory control, real-time combat damage assessment, on-orbit mission control, modeling and simulation tools, space-based internet access and terrestrial network, continuous status reporting, automated vulnerability assessment, multi-level security systems and survivability assessment systems.

    - **Mobile, High Precision Aerospace Ground Equipment.** Includes: carts, modules and trailers that can be configured to any spacecraft or launch vehicle for payload to launch vehicle integration and launch site space system processing, launch vehicle loading and recovery, check-out for launch ready, and non-intrusive testing.

    - **Probatic Systems.** Includes: adaptive, all-weather self-training devices for hazardous material handling, payload optics decontamination; cryogen handling, modules exchange, on-orbit

resupply concepts, and ability to reconstitute and repair asset systems on orbit.

- **Human Factors.** Includes: user friendly logistics decision support tools (LDSTs) and protocols, human-computer interfaces, vertical reality of technical data, area training courses and equipment, allocation of human resources, human centered automated test-bed for check-out of new procedures and intelligent tutoring.

- **Standardized Interchangeable Software, Electrical, Mechanical, Thermal, and Fluids Interfaces.** Includes: autonomous rendezvous and docking systems, fluid couplings, C3 practices, data distribution codes and addresses, and training procedures.

APPENDIX C
Review of Future Space Programs

REVIEW OF FUTURE SPACE PROGRAMS

INTRODUCTION

This study emphasized the logistics deficiencies and requirements for current Air Force space systems. However, a cursory review was made of future Air Force programs in order to consider and intelligently transition logistics technologies from the present to the near term space activities of interest to AFRL.

A dramatic shifting of priorities for development of future capabilities for the Department of Defense was initiated with the release on May 8, 2001, of Defense Secretary Donald H. Rumsfeld's report and recommendations for a major reorganization of the nation's space program aimed at protecting U.S. satellites from enemy attack. This significant realignment would consolidate military space programs under the Air Force and create a new four-star general position as the chief advocate for space programs. This announcement puts into place the "remodeling" of the USAF into a full-fledged aerospace force as recommended in the 2001 Space Commission Report and the JCS Joint Vision 2020.

In view of this recent ground swell of interest in the potential viability of on-orbit servicing, it is important that AFRL continue to closely monitor, and participate in studies that will improve and enhance the sustainment of future space systems as postulated in the high-level reports cited above. Underscoring this recommendation, during the team's review of the DoD Space Technology Guide, it was noted that the guide included recommendations for space servicing technologies. The study team elected to briefly address in the following sections some of the logistics requirements noted in the guide, and other sources, that must be developed to enable space servicing, as it becomes an operational requirement for the space warfighters of the future.

FUTURE SATELLITE SYSTEMS

Several of the space systems listed in the following sections will require some form of space servicing, or on-orbit servicing (OOS), in order to meet their operational mission requirements. The Space Based Laser (SBL) leads the requirement for this future space logistics sustainment capability in order to replenish the fuels consumed to create the lasing beam. The SBL SPO has hosted several meetings over the past two years to bring together government agencies involved in performing OOS studies, or managing or performing on-going technology or prototype developments. These meetings were intended to establish an OOS IPT for the exchange information. The organizations participating in these SBL meetings included AFRL/HESS, AFSPC/LG/DR/DO, SMC/AXE/AXL, DARPA, NRL, NASA, and several aerospace companies including MOOG, TRW, Boeing, Lockheed Martin, and Draper Labs to name a few. Several of the aerospace companies participating in this IPT are also performing IR&D to develop the technologies that will enable an on-orbit sustainment capability for the United States within the next 5-15 years.

In addition, recent bd Systems contacts with the Air Force Space Battlelab, Shriever AFB, CO revealed a renewed interest by the Air Force space operations community in the potential value for an on-orbit servicing capability. A study is underway by the Battlelab entitled Military On-Orbit Servicing Evaluation (MO-OSE) for examining OOS as a potential new operational capability for AFSPC space systems. The study focus and purpose is to present findings and recommendations to the AFSPC General Officer Council (GOC) in late summer or early fall 2001 for approval to include OOS as a sustainment requirement in AFSPC CONOPS for selected space systems. The SBL and SBR are two of the primary projects considered by the Battlelab for OOS capability. Other future systems that may benefit from an OOS capability include:

- Space Based Laser
- Space Based Radar
- Space Based Infrared System
- Global Positioning System – III
- MILSTAR Upgrade
- Global Multi-mission Service Platform
- Hyperspectial Imaging Space Control Missions

FUTURE LAUNCH SYSTEMS

- *Operational Evolved Expendable Launch Vehicles* – The EELV program's development structure was briefly described in Section 4.1. The first Air Force medium launch EELV is scheduled for FY02, and the first heavy launch EELV for FY03 or 04. The Initial Launch Services contracts were recently awarded for the first 28 government EELV launches, scheduled between FY02 and FY06. Boeing has been awarded contracts for 21 of the launches and Lockheed Martin is on contract for the other seven launches scheduled during this period.

- *Space Maneuvering Vehicle (SMV)* – This is an AFRL development project tied to the Air Force Advanced Space Lift program. A fully mature SMV is envisioned as an orbit-to-orbit transportation system that could also perform logistics and servicing missions.

- *Advanced Space Lift* (Possible Reusable Launch Vehicle) – This is an SMC study, performed by Aerospace Corp to conduct pioneering horizontal engineering effort across mission areas and interact with AFSPC and AFRL TPIPTs to help identify and optimal space transportation solution(s).

The Air Force rationale and plans for air and space integration was recently presented in a white paper entitled, "The Aerospace Force: Defending America in the 21st Century." The white paper states that the service's objective is an integrated aerospace force that will swiftly spot, track, and engage military targets anywhere on land, in the air, and in space.

Two years ago, the Air Force Research Laboratory began reorienting its advanced technology programs and budgets placing increased emphasis on space systems. This was seen at the time as an historic shift in perspective and one in keeping with the emergence of an aerospace force in more than name only. In view of the transition underway in the Air Force to emphasize space systems as a priority for the future defense of the nation, it is the opinion of the bd Systems study team that space logistics techniques, processes and technologies should not only build on the current logistics protocols processes and equipment for the near term, but at the same time, the Air Force must direct research attention, planning and resources to develop operational requirements for the in-situ sustainment of future space systems. These space servicing systems of the future could include:

A. *Multi-role Satellites* – The U.S.A.F. is considering initiating development of a multi-role satellite system, that would provide navigation and communication functions. As a growth version, satellite servicing from this platform could be an option.

B. *Space-Based Logistics Platform* – As the strategy of on-orbit servicing becomes more firmly established and the number of space assets requiring service increases, it may be advantageous to locate portions of the logistics support infrastructure in orbit. Prior studies have referred to this space-based support part of the infrastructure as a Manned Tended Platform, Assembly and Overhaul Station, Servicing Facility, Space-Based Support Platform, or General Purpose Space Platform. For purposes of this subtask, we will call it a Space Based Logistics Facility (SBLF). A Space Based Logistics Facility (SBLF) would act as an intermediate node between the ground and the assets to be serviced. It would provide a storage facility for the servicing vehicle between servicing missions and act as the primary basing point for servicing missions to failed or degraded assets.

C. *Microsatellite Systems* – Microsats of appropriate mass, size and capability could:
   - Use easier-to-launch smaller satellites to augment existing constellations during contingency or theater operations.
   - Perform special-purpose or limited-scope missions, such as nuclear detonation (NUDET) detection.
   - Operate as distributed or multifunctional platforms in the performance of several space missions.
   - Support Space Control concepts.
   - Provide unique capabilities to enable new, innovative operational concepts, such as:
     i. On-orbit maintenance, supply and servicing of operational satellites

ii. The use of satellite clusters to provide virtual apertures for sensing operations

The above future space system concepts, as well as others, will require that space logistics sustainment practices, especially launch site processing, will have to keep pace with operational requirements. The AFRL/SV is and has been highly engaged in developing microsatellite systems as evidenced by their programs such as the AFRL Experimental Satellite System (XSS), the TechSat Program, and the ST-5 Nanosat Constellation Trail Blazer program.

SPACE BASED ORBITAL SERVICING REQUIREMENTS

Implementation of a truly space-based logistics and servicing operational capability, for the future Air Force satellite constellations of GPS III, SBIRS, and SBL Spacecraft, drives a need for a facility to be established in orbit from which to conduct space servicing and maintenance activities. The team has termed this "facility" the Space Based Logistics Facility (SBLF).

For in-situ space systems, there are two nodes where maintenance activities can be performed: 1) at an SBLF, or 2) utilizing an SMV with a telerobotic servicer that is dispatched to the satellite location where maintenance may be accomplished in-situ. Both approaches can make use of a supplemental transportation stage SMV, or Orbital Transfer Vehicle (OTV), to accomplish orbit-to-orbit transfers. For efficiency, the servicer will most likely remain in orbit and based at the SBLF, see Figure 4-2. The capabilities that are envisioned for a space-based maintenance and servicing platform include: protected storage for ORUs, consumables and flight support equipment. The SBLF must provide adequate power, thermal conditioning and data processing and communication to handle the platform's and the operational spacecraft's needs during maintenance operations.

The SBLF will be placed in a compromise orbit that complements and facilitates an efficient earth-to-orbit and return transportation system, and can launch an OMV or OTV to readily access the operational orbits of satellite constellations. Some orbit transfer vehicle storage, preparation and servicing will also be necessary at the platform. With an SBLF, there are a multitude of service-based operations that can be postulated for performance on many types of spacecraft and transportation vehicles.

Space Based Logistics Facility

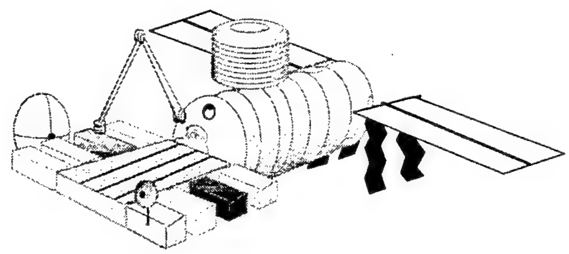


Figure C-1, Space Based Logistics Facility

There will be considerable Flight Support Equipment and telerobotics capability aboard any kind of a service platform of this type, and it too will also require some maintenance and servicing support. This could eventually mean that platforms may at some time be man-tended. If this becomes necessary, the orbital altitude and inclination of a SBLF will remain outside the radiation belts of the earth. The optimization of this facility's location will be a constant set of compromises dependent upon the development of on-orbit servicing transportation means, and the mix and types of spacecraft to be serviced. The positioning of the platform could change over time.

ORBITAL EXPRESS

A golden opportunity exists for AFRL to capitalize on the success of the Orbital Express demonstration scheduled by DARPA in 2004 – 2005. There is expectation that considerable residual assets could be left on orbit that could be transitioned to establish an Interim Operational Capability (IOC) of an on-orbit servicing system for the Air Force. Should the Air Force accept and establish a supporting infrastructure for the residual assets, requirements must be established and developed soon to ensure success of this opportunity. With a minimum ground infrastructure that includes a dedicated control center, the Air Force could accomplish simple missions initially to demonstrate the military utility of satellite servicing. Following in an evolutionary method, additional capabilities could be added to extend the capabilities to include more complicated servicing scenarios. Equally important, the basic set of OE space assets could become a space terminus for the RLV, SMV, and OTV programs now in development.

Concurrent with the DARPA phase of the project, the Air Force can prepare the support infrastructure in parallel with full visibility of the operating hardware, and gain invaluable

knowledge from participating and/or observing the experiments to be performed. This concurrent effort will make the IOC transition easier with considerably reduced risk and cost than would normally be incurred.

ORBITAL TRANSFER VEHICLES (OTV)

Both the Air Force and NASA have long identified the need for OTVs of various types and sizes for supporting operations for orbiting systems. Different applications have led to different design and operational concepts for several orbit-to-orbit diverse mission objectives. OTV operational cost savings and quick response capability offers to serve various logistics and on-orbit satellite needs. A primary advantage of this space transportation vehicle would be its capability to provide repeated operational sorties in orbit over an extended time period, with sufficient maneuvering performance to reach different destinations in a given orbit or nearby orbits, carrying a substantial payload mass, usually in the departure (from a Space Based Logistics Platform) or return phases.

Figure C-1 lists the OTV's operational functions and orbit transfer requirements with an indication of the frequency and duration of sorties and the range of maneuver velocities, the principal benefits of these mission support functions, and the degree of complexity they demand. Also listed are any attachment or special equipment requirements to perform these functions. The projected time frame of using these OTV capabilities is estimated to indicate at what stage of the on-going development any new attachment features and support equipment have to be available.

OTV Operational Functions, Utilization and Benefits in Various Applications

	Space Station			Close Satellite Inspection	Constellation Support	Individial Satellite Support
Function	Resupply	Waste Disposal	Circum-navigate	Friendly or Non-Friendly	Resuply, Deorbit	Resupply, Retrieval, Refueling
Utilization Start	Early at A.D.*	Early at A.D.*	Early at A.D.*	Early at A.D.*	A.D. +2 yrs.	A.D. +2 yrs
Sortie Frequency	High	Low	Low	Low	Medium	Medium
Task Complexity	2-3	2	2	3	7-10	5-10
Maneuver Velocity, m/sec (rt)	10-20	350	20-30 depending on distance	20-30 depending. on distance	400-750 depending on distance	300-500 depending on distance
Attachment Kits Needed	Retention Devices	Retention Devices	None	None	Grasping Arms	Docking Fixture Refueling Equip

Figure C-2, OTV Operational Functions and Orbit Transfer Requirements[2]

SPACE BASED LOGISTICS FACILITY FOR THE SPACE BASED LASER PROGRAM

In any consideration of in-space logistics functions and on-orbit servicing for SBL, a series of trade studies must be performed to determine the economic advisability and the mission feasibility of basing a dedicated logistics/servicing capability on-orbit versus on the ground. The Air Force Space Based Laser program Architectural Systems study contractors (TRW, Boeing, Lockheed Martin) in 1999-2001, and the AFRL Space Logistics Requirements study, Phase II, completed by PRC in 2000 evaluated the above trades.

SBL sizes, number of spacecraft in the operational constellation, constellation parameters, launch cost, and servicing requirements were studied in a metric of trades and assumptions. Low Life Cycle costs and high mission readiness values led the list of evaluation factors.

[2] Reference: AIAA 99-4439 Mission Design and System Requirements for a Multiple-Function Orbital transfer Vehicle, by H. F. Meissinger and J. Collins, Microcosm, Inc. AIAA Space Technology Conference 28-30 September 1999, Albuquerque, New Mexico

Because the SBL program lacked the maturity of a definitive spacecraft design and a finalized concept of mission operations, no concrete, defendable conclusions were reached; however, the TRW and PRC work gave strong indication that a SBLF dedicated to the SBL constellation could be cost effective. Under certain SBL assumptions, a life cycle cost saving of about 30% is possible by space-basing logistics and servicing activities.

APPENDIX D
Space Payload Traffic Model

SPACE PAYLOAD TRAFFIC MODEL

INTRODUCTION

Comprehensive analysis of space logistics covers a broad range of system engineering topics; from generating: ground and space based payload traffic models, workable simulation programs, and proof-of-concept demonstrations to verification of newly developed logistics decision support tools.

This section addresses space payloads traffic models. Payloads, or satellites, are the only Air Force operational systems where no post deployment repair, maintenance or upgrade capability is routinely provided. The result is expensive space systems and high cost of transportation to space.

Before a space logistics master plan is created, data must be available to answer, as a minimum, questions such as:

- What are the number of payload types that are proposed to fly in the next 10 years
- How big and complex are these payloads?
- Where are these payloads going to be placed [3](to what orbit)?
- What regions of the world are developing these payloads?
- What are the launch vehicle systems that will send these payloads to space?

The space payloads traffic model is presented via the above 5 questions, with responses providing a framework from which to make logistics projections about future Air Force space assets based on relatively "hard information." The numbers to follow are not forecasts but rather a point-in-time snapshot of what is firmly expected by satellite and launch vehicle developers.

The 2147 payloads in the model represent a reference point. Since the Teal Group identified 2147 payloads proposed at present, we can assume that one-fourth of these or more will eventually be orbited. We can also assume that in the next 10 years, at least an equal number (500 or so) of new payloads, now unidentified, will be launched.

By the same thinking, Mr. Caceres of the Teal Group believes it would be a stretch to assume that more than twice as many payloads as now proposed will actually be built and launched. He advised the study team that something drastic would have to occur within industry and the government (DoD and NASA) to see anywhere near 5000 payloads launched through 2009. The only factor that could create such a market would be an exponential drop in launch costs. No one foresees this happening in the near future.

[3] Much of the information was provided by Mr. Marco Caceres, Research Analysis for the Teal Group, Fairfax, VA. His phone number is 703) 385-1992, e-mail is mc aceres@tealgroup.com. He has authorized the use of the information in this AFRL report.

PAYLOAD TYPES

Figure D-1 shows the disposition of payload types from 2000 through 2009. About 65% of the payloads are commercial COMSATs. The second largest grouping is NASA satellites – 19%. The bulk of these are scientific and Earth Observation vehicles. Note that military satellites only account for some 8% of the total, fairly evenly divided between early warning, technology, reconnaissance, navigation, and communications spacecraft. The other payload category consists of various manned missions, experimental spacecraft and commercial imaging and navigation satellites.

Payload Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Military Satellites											
Early Warning	2	1	4	4			12	12			35
Tech Development	28	2		4							34
Reconn & Surveillance	1		2	5		3	10	10			31
Navigation	4	7	6	4	2	3	3	1			30
Communications	3	1	10	1	1	1	4	3	3	2	29
Earth Obs & Met	2	1	1					1	1		6
Subtotal	40	12	23	18	3	7	29	27	4	2	165
Commercial COMSATs	121	154	196	212	173	185	206	138	16	61	1482
NASA Satellites	115	48	44	40	19	12	6	63	54	1	402
Other Satellites	46	38	37	23	7	8	2			1	162
Total	**322**	**252**	**300**	**293**	**202**	**212**	**243**	**228**	**74**	**65**	**2191**

Figure D-1: Proposed Military Payload Unit Types

With the Air Force showing only 165 payloads launched over the 10 years compared to NASA's 402 and commercial COMSATs launching 1382, it seems advisable to examine sharing ground operations and launch site logistics with civilian organizations. This provides a means of reducing storage and launch site costs where mission urgency and security factors permit.

The Air Force Space Command (AFSPC) and the Space and Missile Center (SMC) are planning future military payloads that involve pushing new missions into space designed to provide more capability out of single spacecraft. Shifting airborne early warning from aircraft to space is one idea under consideration by the Air Force. Another priority need considered by military leaders is building more versatile spacecraft. It becomes obvious that the future is in multi-mission platforms.

The Air Force has a history of piggybacking classified payloads on some selected satellites, effectively assigning them a multi-mission mode. However, the new arrangements, in future planning concepts, would be much more structured with entire constellations – such as the GPS Block 3 navigation satellites – equipped to conduct intelligence-gathering, for example, as well as providing global navigation and timing service.

The AFSPC and SMC seek not only systems that can conduct several missions with a single sensor suite, but also individual spacecraft that can carry several types of sensors for multi-spectral and fused-picture sensing of targets. Such developments would match what the Air Force has done with its tactical aircraft that have evolved to platforms capable of carrying imaging reconnaissance pods and laser-designation systems. Meanwhile, most space payloads remain single purpose, such as the Space-Based Infrared System constellation intended for missile warning and tracking.

The intent of the above dissertation on Air Force space programs is to point out that when the Air Force payloads change in character, their logistical tools and techniques must be ready and capable to accommodate changes. Multi-mission spacecraft or platforms will require a new look at how payloads are developed, tested, stored, launched, operated in orbit and how the users of the space acquired information perform their various action and reaction functions. Additional discussions on the subject of multi-mission platforms are provided later in this report.

PAYLOADS BY MASS

Figure C-2 depicts the masses of the 2147 payloads in the Payloads Traffic Model. This information is of interest to launch service providers, who are looking for the most efficient way to configure their vehicles to adapt to payload shape and size. Figure D-2 shows that 41% of payloads can be classified as small satellites with masses of between 1 and 2205 lbs. This bracket includes no Air Force operational spacecraft.

PAYLOAD MASS		NO PAYLOADS	PERCENT
1-220 lbs	(1-100 Kg)	207	10
221-1102 lbs	(101-500 Kg)	370	17
1103-2205 lbs	(501-1000 Kg)	307	14
2206-6615 lbs	(1001-3000 Kg)	454	21
6616-11025 lbs	(3001-5000 Kg)	136	7
11026-55125 lbs	(5001-2500 Kg)	67	3
OTHER		**606**	**28**
TOTAL		**2147**	**100**

Figure D-2: Proposed Payloads by Mass, 2000-2009

Approximately 21% of the payloads weigh between 2206 and 6615 lbs. This includes Air Force spacecraft such as the Defense Meteorological Space Program (2500 Lbs), the Global Positioning Satellite 4138 lbs), and Defense Satellite Program (5170 lbs). Milstar, a relatively heavy military COMSAT at 10,300 lbs, falls within the 7% category. The KH-11 satellite at 30,000 lbs and the Space Based Laser estimated to be between 50,000 and 80,000 lbs fall in the 3% group.

There is a direct correlation between payload weight and satellite complexity. It, therefore, follows that the logistics issues and requirements increase in scope and cost with payload weight. When the SBL becomes operational (estimated in 2020) a new set of logistics procedures will be necessary if the procedures in effect at that time cannot be upgraded.

PAYLOADS BY ORBITS

To which orbits will the payloads be launched? Figure D-3 indicates about 60% of the payloads are destined for Low Earth Orbit (LEO) – most of them between altitudes of 500 and 800 N. Miles. This orbit range includes the DMSP and GOES spacecraft, as well as the future Space Based Laser payloads. Many payloads in this group are directed to high inclination or near polar orbits.

PAYLOAD MASS	NO PAYLOADS	PERCENT
Low Earth	1351	63
Geostationary	400	21
Medium Earth	184	9
Elliptical	93	4
Lunar/Solar	27	1
Planetary	34	1.5
Other	18	0.5
TOTAL	**2147**	**100**

Figure D-3: Proposed Payloads by Orbit, 2000-2009

About 21% of the payloads are geostationary satellites. The military COMSATs such as MILSTAR are GEO birds. The Defense Space Program also operates at GEO, but the Global Positioning System (GPS) is in a Medium Earth Orbit (MEO). The Air Force has very few satellites in elliptical, lunar/solar, and planetary orbits.

From a logistics perspective, the Air Force GEO payloads pose launch site and orbital control problems associated with large launch vehicles, upper stage operations, and the precise placement of the payload on their assigned GEO station.

PAYLOADS BY REGION

While a number of 2147 payloads provide an interesting starting point for traffic planners and forecasters, there is a need to know more precisely who is driving the market if any kind of a global logistics program is attempted. Figure D-4 identifies 2147 payloads by region.

LOCATION	NO PAYLOADS	PERCENT
North America	1226	572
CIS	359	168
Europe	299	13.6
Asia and Pacific Rim	169	7.9
Latin America and Caribbean	39	1.8
International	33	1.6
Africa and Middle East	22	1.1

Figure D-4: Proposed Payloads by Region, 2000 –2009

It is clear from this figure that it is the United States government and commercial companies are the main payload customers throughout the world. These users account for 57% of the space payloads. Within the U.S. share, roughly 75% of the payloads belong to commercial ventures, with the remaining 25% to U.S. Government agencies (DoD, NASA, and NRO).

Fewer than 40% of the total payloads are proposed by Russia and countries in Europe, Asia, and the Pacific Rim region. Among the Europeans, the largest customers are the French, British, and Italians. France is proposing about 35% of Europe total, Great Britain 11% and Italy 9%.

In all, some fifty countries and about 150 government agencies, organizations, companies, institutes, and universities are represented in the logistics traffic model as payload customers.

PAYLOAD BY LAUNCH VEHICLE

Last comes the question, "Who will launch the payloads?" Figure D-5 breaks down the traffic model data by launch vehicle program. Note that of the total of 2147 payloads over the next 10 years, only about 46% of them have an assigned launch vehicle at this point. There are 1167 payloads (54%) with no designated launch system. Some of these could be United States payloads.

LAUNCH VEHICLE	NO PAYLOADS	PERCENT
United States		
Delta	152	7
Atlas	41	2
EELV	38	2
Pegasus	23	1
Start	21	1
Titan	15	0.5
Minotaur	13	0.5
Space Shuttle	67	3
TOTAL	**(370)**	**(17)**
Europe	208	10
Ukraine (Tsyklon & Zenit)	63	3
Russia (Cosmos & Soyuz)	54	2.6
China (Long March)	30	1.5
Japan (H-2)	27	1.3
India (PSLV & GSLV)	20	1
U.S. Russia (Proton)	142	6.6
Russia/Germany (Rockot)	56	2.5
U.S/Ukraine (Sea Launch Zenit)	10	0.5
OTHER	1167	54
TOTAL	**(1777)**	**(83)**
GRAND TOTAL: 370 + 1777 = 2147 (100)		

Figure D-5: Proposed Payloads by Launch Vehicle, 2000-2009

Five launch vehicle programs account for 64% of the assigned payloads. These include Arianespace's Ariane 4 and 5, Boeing Delta II, III, and IV, International Launch Services' Proton K and M, NASA's Space Shuttle fleet, and Eurochot Launch Services' Rocket.

The Air Force/NASA Space Maneuver Vehicle is in the technology demonstration phase. Boeing is the contractor. When operational, it will deliver a 1200 lbs payload from LEO to GEO.

Figure D-5 also shows the Delta, Atlas, and Titan vehicles with payload launch assignments from 2000 through 2009 even though these vehicles are said to be supplanted by the Evolved Expendable Launch Vehicle (EELV) at some point in the next several years.

The challenge for Air Force space payload planners will be to develop the logistics system, ground and space, to enable programs like the advanced GPS, SBIRS, and SBL to deploy and operate their constellations of satellites in a mission effective manner.

SUMMARY

The Air Force will deploy only about 8% of the space payloads from 2000 through 2009 (165 out of 2147.) However, due to their unique flexible sustainment requirements associated with: precision engagement, rapid global mobility, agile combat support, and information superiority, their logistics systems will be the standards to which other agencies (U.S. and international) will be compared.

The Payloads Traffic mode – embodied in the above discussed 5 topics – must be updated yearly so that the Air Force logistics managers will have a numerical basis from which to develop logistics tools and techniques necessary to keep their sustainment policies current and effective.

The payloads traffic model will also help in Air Force decisions to co-share logistics storage, launch, control, and operational equipment with other U.S. or international agencies.

APPENDIX E
Preliminary LDST Concept

PRELIMINARY LDST CONCEPT

During the initial start up of the Space Front End Logistics study, bd Systems was tasked to prepare an overview of a preliminary approach for the Logistics Decision Support Tool (LDST) to address the needs of the Air Force Space and Missile Systems Center Acquisition Logistics community. The following charts present the initial concept for the decision tool that was developed and subsequently expanded by the TRS prime contractor, TASC.

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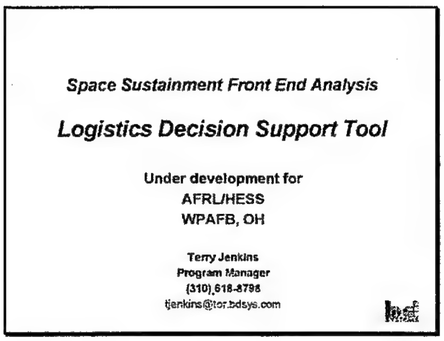

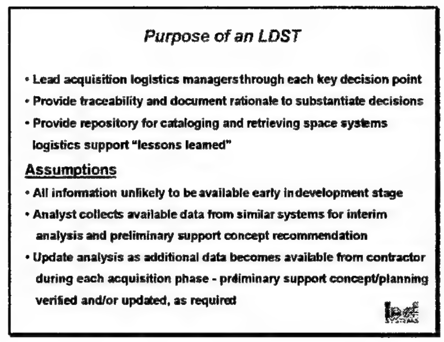

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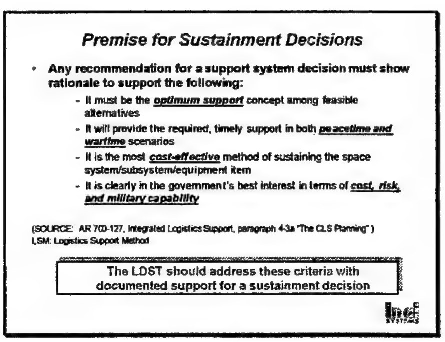

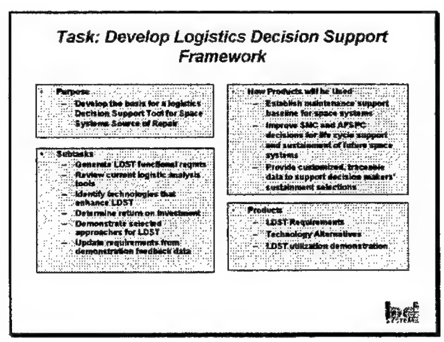

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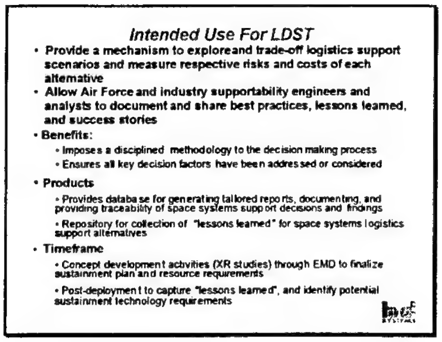

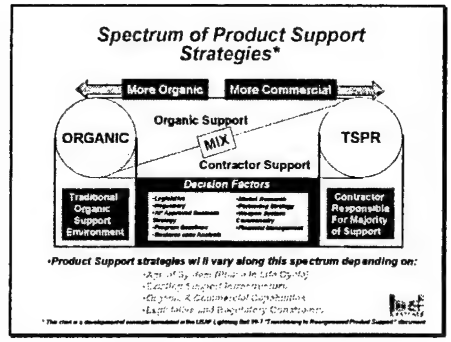

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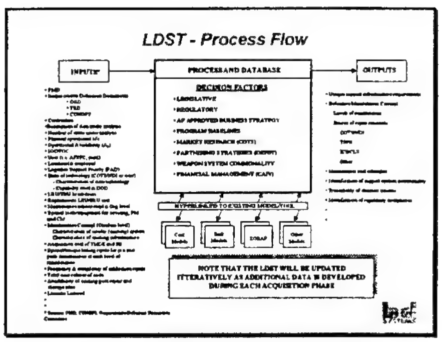

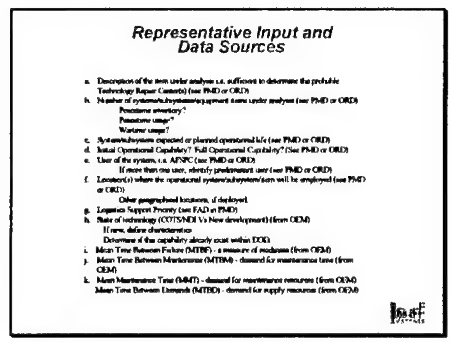

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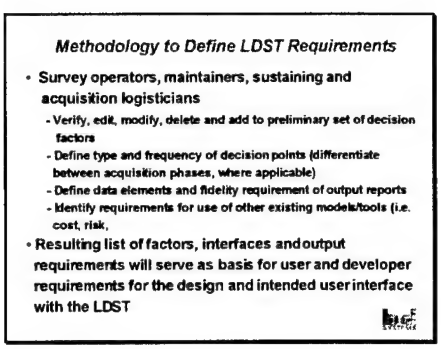

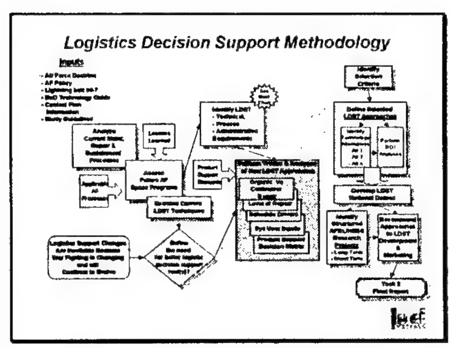

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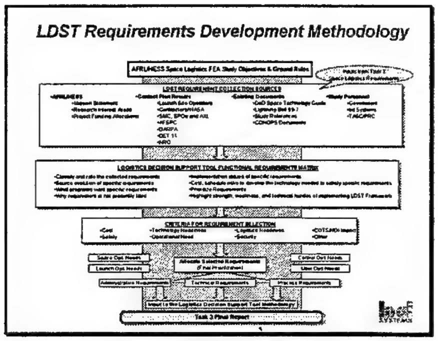

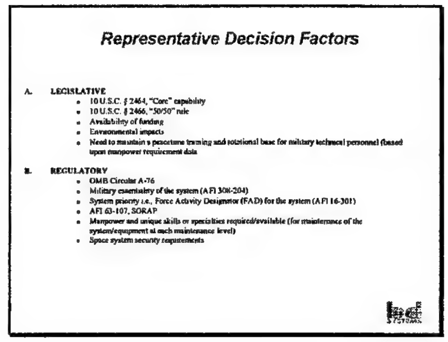

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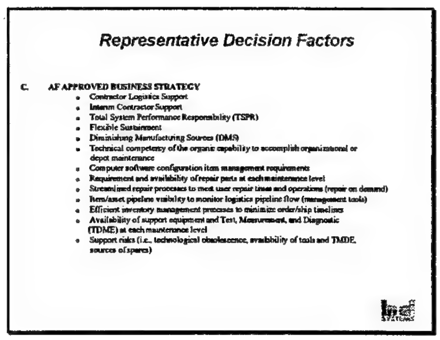

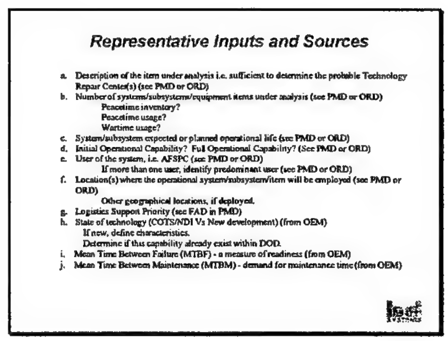

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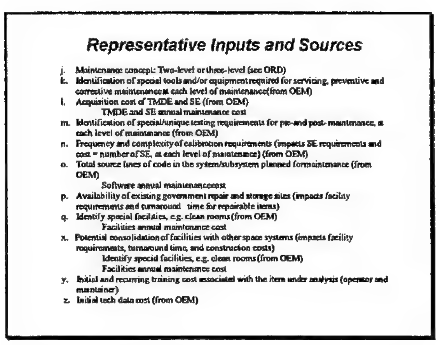

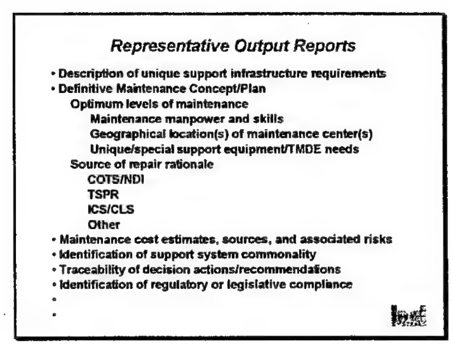

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Expected Application Of LDST

__Potential users:__ **SMC SPO's, AFSPC, HQ AFMC, HQ IL/AQ, and Aerospace Industry**

- **SPO's Acquisition Logistics Manages**
  - Determine optimum support approach in detail
  - Document the decision process
  - Defend recommendations and positions throughout the acquisition process (traceability) - Feeds the SAMP
- **AFSPC Operations and Maintenance**
  - Assists in verifying that requirements (mission critical) are met
  - Allows full participation in and input to the support concept development and maintenance planning process
  - Ensure command policies and strategies are being met
- **HQ AFMC, PEO, and HQ IL/AQ**
  - Insight/understanding of alternatives considered and basis for recommendations
  - Back-up summary and/or detailed rationale to substantiate recommendations

Space Sustainment FEA Study Potential Benefits

- **The products will provide a fresh and current look at USAF requirements for logistics support of space systems**
- **Potential logistics technology development areas will be identified for AFRL investment decisions**
- **A framework will be prepared for developing a Logistics Support Decision Tool for SMC, OOALC and AFSPC users**
- **A natural user work group will be re-established within the USAF acquisition, development, operator, sustainer, and user communities to address future space logistics issues and requirements**

Slide 10

BACKUP

REFERENCE SUBJECTS

[illegible]

APPENDIX F
Technology Development and Roadmap

TECHNOLOGY DEVELOPMENT AND ROADMAP

TECHNOLOGY DEVELOPMENT PROCESS

The technology development process for 6.3-funded research concepts, shown in Figure F-1, involves identifying needs within the operating Air Force organizations, exploring potential technology solutions that could be applied, and conceptualizing approaches to the solutions to the problems.

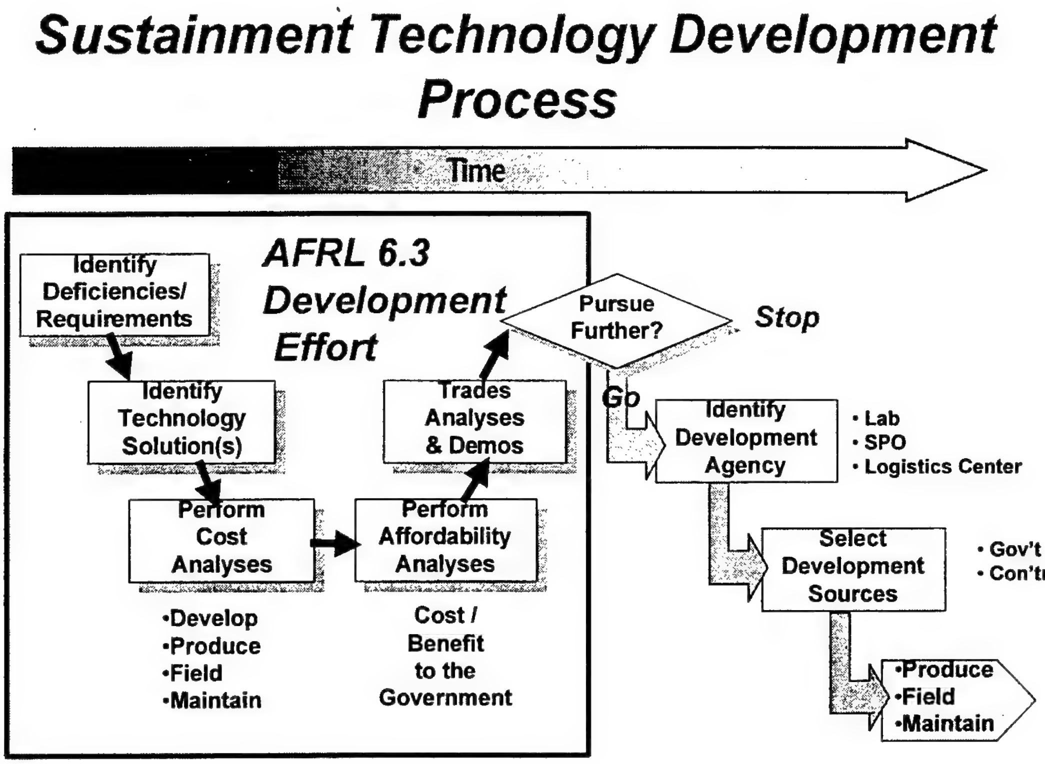


Figure F-1: Technology Development Process

It is important to clearly identify the needs so that research efforts may be focused on specific areas of deficiency to solve real problems. Technologies that could be applied might be mature and being used or developed for other uses. Emerging technologies that are changing the way business is being done should also be examined for application as well.

In formulating a potential concept for development other than a design solution, the cost and affordability analyses provide insight to the developers as well as the potential user budget planning information for any eventual implementation.

An important product of the research process is to develop and demonstrate a prototype system or item that can be tested and demonstrated. This is true for hardware and

software. It is easier for potential users, sources of funding, and approval authorities to see and understand the concepts and benefits of any development if they can touch and operate a reasonable prototype of the development item.

After a project has progressed through a prototype demonstration phase, trades and analyses can be performed to decide if further development is warranted. Additionally, the location or agency that would carry forward any development effort for the technology should be determined at the end of the 6.3 effort.

TECHNOLOGY DEVELOPMENT SEQUENCE
The development plan may be unique to each individual item. Typically, there are four phases as shown in Figure F-2. The investigative Phase explores the need and the potential technological solutions that could be applied. In the effort described in this document we went to the space sustainment acquisition and user communities to get their requirements and then bounced those requirements against the technology areas that AFRL/HESS has expertise.

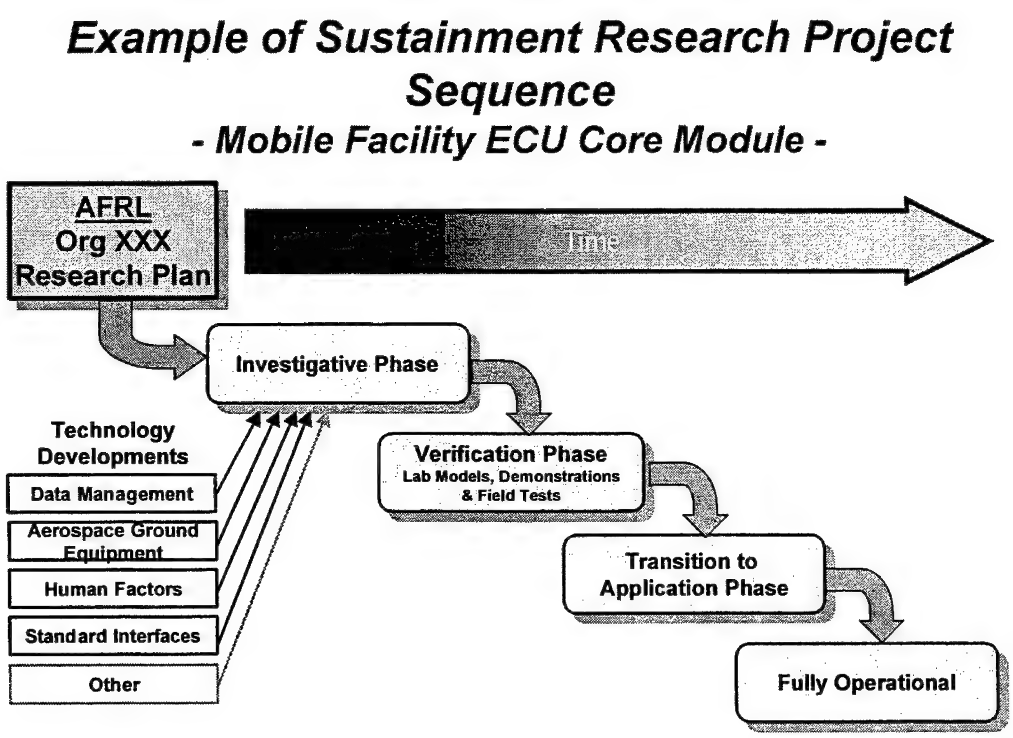


Figure F-2: Technology Roadmap Sequence

The Verification Phase involves developing laboratory models or prototypes. These items then are tested, evaluated and demonstrated to determine if the concept has enough merit to continue development. If the model or prototype is mature enough field tests by actual operating personnel is often valuable to the development process.

After a concept passes through the verification phase the transition to application phase takes the item to a higher level of development. At this point a determination needs to be made as to the agency that will carry the development to a higher level, a transition agency. If more 6.3 -type development effort is needed it may be prudent to retain the effort at AFRL. If the maturity and value of the concept is sufficient where another laboratory, a SPO, or logistics center more logically does the development, then a plan for this transition should be developed and implemented. As the development progresses and implementation is assured, planning for the installation and support must be accomplished. This planning would cover such activities as introduction into the inventory, modification procedures, training efforts, operations and maintenance procedure updates and any adjustments required to the supply system.

Once the application has been verified and the deployment decision has been made, the planning that was done in the previous phase must be implemented along with the logistics resources. Procedures need to be updated, operators and maintainers need to be trained, and other transition activities need to be accomplished.

TECHNOLOGY DEVELOPMENT ROADMAP

Any plan to improve Air Force space logistics equipment and procedures must account for tomorrow's needs, tomorrow's technology and today's fiscal reality. A well thought out space logistics technology development roadmap should build a "business case" that leverages logistics modernization and provides augmented program acquisition and sustainment capabilities. This section suggests a format for a multiphase space logistics technology development program.

When the study team tied technologies to the previously presented 15 candidate space logistics research concepts, and performed a commonality analysis, it was determined that all the associated technologies areas fall into six categories that are compatible with the mission of AFRL/HESS. The technology areas are:

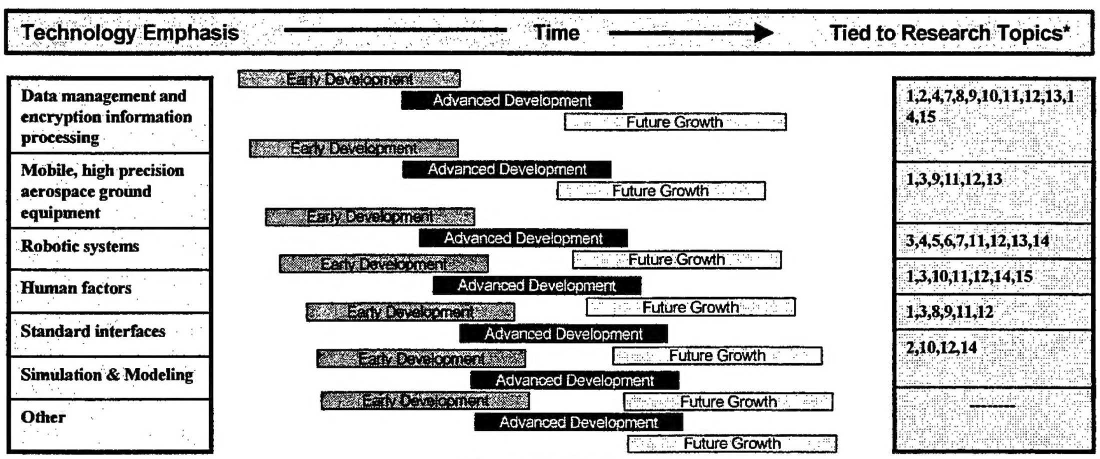
- Data management and encryption information processing
- Mobile high precision ground equipment
- Robotic systems
- Human factors
- Standard Interfaces
- Simulation and Modeling

Most research concepts that were identified use multiple technologies for implementation. The dependency on several technologies can require iteration in the development process to assure the viability of the total concept. With each improvement there needs to be testing so that the impact on collateral elements of the space system can be assessed. These improvements are evaluated in test beds and prototypes in an iterative manner until the development is finished and the final design is optimized.

Each of the above six technology areas will undergo a three part time phased series of events. The phases are:

- o Early development, usually one to three years
- o Advanced development, estimates range from two to five years
- o Future growth projected at up to ten years after the technology has reached application to a logistics system

Figure F-3 shows this normalized time phasing for the six technology areas, their interface with each other, and their tie to the 15 logistics research concepts.



***Research Topics**

1. Mobile Facility ECU Core Module	6. Optics Decontamination	11. Commonality Assessment
2. SBIRS Crew Trainer	7. Leak & Hot Spot Detector	12. EELV Model & Simulator, Integration/Test
3. Propellant Loading Equipment	8. On-Board Data Recorder/Telemetry Package	13. Launch Pad Damage Assessment
4. Remote Surface Inspector	9. Microsat Launch Processing	14. Logistics Decision Support Tool
5. Diagnostic System	10. Constellation Logistics	15. Maintenance Data Collection System

Figure F-3: Sustainment Technology Roadmap

The key considerations of any space logistics technology development program include:

- o Cost of bringing the technology through transition to operational application
- o Location where the logistics function will be performed, that is at the (1) government or contractor's assembly, integration, and test facility (2) launch site, or (3) mission control station

- Who will perform the logistics function – organic or contract personnel or a combination of both
- Commonality of hardware or processes to multiple customer organizations
- Impact on in-use standards, protocols and wing policies
- Potential for growth to include space-based and on-orbit logistics operations

KEY LOGISTICS CONSIDERATIONS

The key considerations of any Air Force space logistics system and maintenance program can be collected under nine principal elements listed below that will change with time and program maturity. Examples of key considerations under each element include:

Cost

- Space logistics systems must be cost effective and program enabling
- Logistics pricing policy must be established for users in advance of spacecraft design and mission operations
- A national investment in the logistics infrastructure is required prior to achieving space program life cycle costs savings

Logistics location

- Near term strategy will address logistics and maintenance sustainment of space assets in low earth orbits
- The evolution of the logistics strategy to polar, high inclination, or GEO stationary orbits will be a function of the cost benefits associated with the maintenance of assets in these orbits
- Users of serviceable space assets must locate these assets in orbits compatible with an operational logistics system
- The maintenance of satellites at the U.S. Space Station will occur when a logistics and servicing capability is available at the Station and when such sustainment maintenance is warranted as paced by user requirements and economics
- Logistics location – where and who will perform the logistics functions, organic or contract personnel or a combination of both? Impact of new logistics standards, protocols, and training on wing policies

Servicing Functions

- Logistics and servicing of satellite systems is any activity performed on the ground or on-orbit to assemble, maintain, repair, resupply, upgrade, deploy, retrieve, or return various space systems, satellites or facilities
- How, when, and if each logistics function is performed on a space system depends on the technology status of the function, maintenance hardware availability to accomplish the work, operational need for quick response, number and location of the spacecraft to be maintained, and cost of the servicing mission versus spacecraft replacement cost

Common Hardware

- Baselining and development of generic maintenance equipment hardware and tools for various classes of spacecraft will preclude each program office for having to procure its own set of hardware and maintenance database
- A designated government organization (the Air Force or NASA) must own and issue (loan) the generic maintenance hardware to user project offices

Transportation

- The operational satellite logistics and servicer system must be compatible with expendable launch vehicles, the Space Shuttle, the SMV, and the OTV which are vital parts of the national logistics infrastructure

Standards

- Maintenance interfaces must meet recognized and agreed to interface standards
- Work should be accelerated to determine and define the requirements for robotic hardware/software and standard maintenance interfaces for satellite servicing

Operations

- Safety of the crew and equipment is paramount in mission planning, timelining of events, and selection of infrastructure elements to accomplish on the ground and on-orbit logistics objectives for all programs
- Strong emphasis should be placed to identify compatible issues in the design of satellites and robotic maintenance systems that promote a cooperative environment for blended human factors and automated servicing operations

Technology

- A satellite maintenance logistics system flight demonstration program, sponsored by AFRL/HESS, will provide the confidence required to commit to a national operational set of logistics functions
- There is a need to quickly mature the six critical technologies associated with space maintenance described above
- There is also a need to utilize ground testing and simulation facilities for developing a remote logistics capability, first for ground-based operations and then for on-orbit missions
- Specific and directed logistics research must focus on addressing the following questions: (1) where are the high (early) technology payoffs? (2) Are they specific to users or generic? (3) How does the sequence of technologies affect the solution via flight demonstrations? (4) How much innovation is enough?

Growth Capability

- Satellite servicing infrastructure, and the related hardware/tools inventory, can evolve with mission needs
- All elements of the logistics infrastructure must have built into the respective program a growth or extended capability. These separate growth plans should be integrated and factored into the national space logistics program so they will be ready when the future Air Force programs come on line in the next five to ten years